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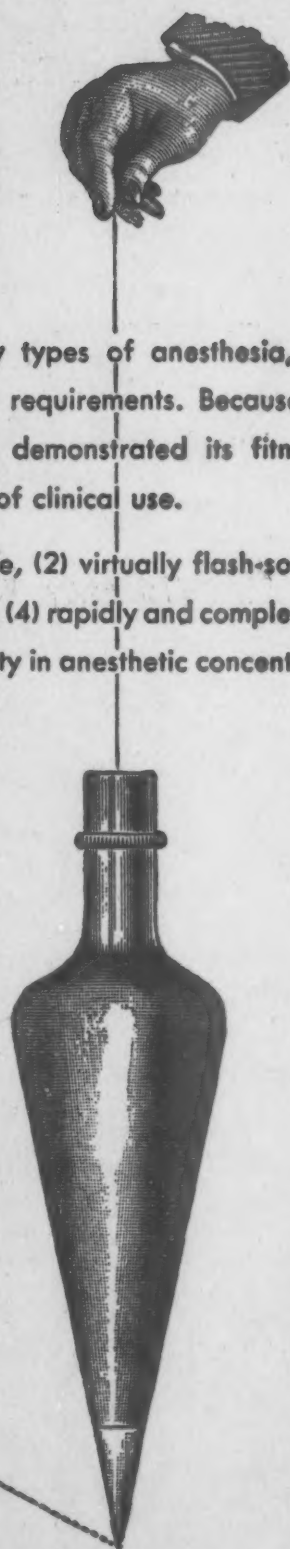
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## EXPEDITIOUS CARE OF FULL-THICKNESS BURN WOUNDS BY SURGICAL EXCISION AND GRAFTING\*

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AT THE TIME of the precipitous entry of the United States into World War II, when burns loomed as an incalculable loss of man power to the Armed Services, review of the burn problem suggested that changes in the surgical handling of the burn patient must be introduced. Considering the suddenness with which a limited number of trained medical personnel might be overwhelmed by a large number of burn casualties under conditions of warfare, too much time and attention were lavished on the wound to the neglect of the internal economy of the casualty. There was urgent need for simplification of the wound treatment. From studying the natural history of the burn wound it was found not only that tannic acid as a surface treatment was injurious but also that in burns of partial skin-thickness, which constitute the majority of burn wounds, the best care could be attained by ignoring the wound, except for protecting it with a simple ointment dressing, and abandoning the washing and débriding ritual of the tannic acid method. Experience with this simplified method was obtained under disaster conditions in the care of the victims of the Cocoanut Grove fire.<sup>1</sup> Subsequent experience with such therapy under civilian conditions will be considered in a subsequent paper.<sup>2</sup>

The simplified therapy of the burn wound, tailored for disaster conditions, introduced no reform in the care of the full-thickness wound. The slough of such a wound was allowed to separate spontaneously or by the aid of wet dressings applied at later dressings. Although invasive infection was usually held in abeyance by chemotherapy, all such full-thickness wounds became infected and it was necessary to linger and await the appearance of healthy granulations before contemplating grafting. By reducing contamination through observance of strict precautions at change of dressings and of maintenance of the optimum nutritional balance, it was feasible to graft some full-thickness wounds at 25 days after injury, but in other patients with more extensive burns, inevitable infection led to debility and the casualty languished for months

\* The work described in this paper was done under a contract recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Harvard University.

before all wounds were successfully healed. The full-thickness burn wound emerged during the course of the war as economically and psychologically the most important unsolved problem in the surgical management of the burn patient.

Rehearsal of the life span of the full-thickness burn wound suggested significant differences between it and that of the partial-thickness burn wound other than the absence of viable epithelium. Whereas, in the superficial burn the intact epidermis, even though dead, acts as a protective barrier against the entrance of organisms, in burns where the heat has been of sufficient intensity to cause full-thickness destruction, the epidermis is no longer intact. It is usually cracked or torn and the wound is, therefore, violate. Instead of being bathed by a fluid medium, the more intense heat has coagulated the tissues. Chemotherapeutic agents, able to permeate the wound of partial thickness, are unable to penetrate the coagulum of the full-thickness wound. Such devitalized tissue, devoid of a means of communication with the body fluids, and presumably of a lowered oxygen tension, offers an enticing culture medium to organisms, including the virulent anaerobe. Any counter measures which would intercept infection and lead to expeditious healing must, therefore, include prompt removal of this necrotic tissue. If removal were immediate, and closure of the wound accomplished by grafting, the inevitable contamination of the burn wound would be prevented from developing into an infectious process.

Since the multiplication and invasion of bacterial organisms is rapid, the only means which could possibly eliminate the necrotic tissue before infection develops, is direct surgical excision. The elimination of infection should be accompanied by improved nutrition of the patient and prompt closure of the wound followed by minimal scarring, disability and disfigurement. The early healing should achieve a short period of hospitalization, an economy of manpower and an hopeful outlook by the patient.

The limits of such aggressive surgery suggesting themselves were threatening physiologic imbalance of the patient, a meager amount of donor skin in the extensively burned patient, and inability to recognize with certainty full-thickness destruction of the skin. The physiologic imbalance could be thwarted by prompt and adequate shock therapy, and the quandary over the depth of destruction by increasing experience. The limitations of physiologic imbalance and difficulty of recognizing full-thickness destruction immediately would be exaggerated under conditions of warfare. Under such conditions it might not be possible to maintain adequate physiologic balance or to find the time for scrutiny of the burn wound. Indeed, hospital facilities might be elusive.

The refractoriness of the full-thickness burn has impressed a number of surgeons during the war years. Connor and Harvey, at New Haven, have approached the problem by dissolving the slough chemically. Pyruvic acid starch paste has been found to accelerate the separation of slough, permitting grafting of the area as early as six days after applying the acid.<sup>3</sup> Other workers have tried surgical excision of the slough. Young,<sup>4</sup> in 1942, reported a case, with a burn of 8 to 10 per cent total extent, part of which was excised and grafted three and one-half hours after injury. Ackman, *et al.*,<sup>5</sup> at Montreal,

## FULL-THICKNESS BURN WOUNDS

have reiterated the importance of expediting the closure of the full-thickness burn wound and have, after surgical excision of the slough, grafted extensive wounds as early as 12 and 16 days following injury. We were privileged to see Gerrie, of this Montreal group, excise the slough of a full-thickness burn wound on the 12th day, with immediate grafting; the take was 80 per cent successful. Gerrie removed the slough by shaving it off with a sharp knife rather than by excision of the wound. Saltonstall and Lee<sup>6</sup> have reported the grafting of a patient on the 16th day following injury after excising the slough. More recently, McCorkle<sup>7</sup> has used surgical excision to expedite healing and has reported doing this on the 7th day following injury.

The rationale and theoretic limitations of the program for the expeditious care of full-thickness burn wounds by surgical excision and grafting have been tested. Certain patients received the ideal treatment, that is excision of the full-thickness wound destruction within the first hours after injury, with immediate closure of the wound by split-thickness grafts. Patients in whom physiologic balance was assured were chosen. In other patients, excision of the wound was arbitrarily postponed for a number of days and penicillin administered in that interval in order to see how successful this agent would be in holding invasive infection in abeyance. The initial interval chosen was seven days because it was considered that during this period from injury to excision and grafting it would be feasible for a burn casualty to be dressed and transported from, for example, France to a Base Hospital in England where surgical facilities were available, and physiologic balance of the patient secured. Later this interval was both shortened and lengthened for evaluation of the method.

### CLINICAL OBSERVATIONS

The cases of full-thickness burns at this hospital which have been found suitable for early surgical excision and grafting have been divided into three categories according to the extent of the burn and the interval between injury and surgical care. The burns have included those produced by heat, chemicals and electricity. In all, 38 patients with 52 wounds have been so treated.

1. Circumscribed full-thickness burns excised and grafted within the first hours after injury constitute one category. There are ten such cases (Table I), and the report of one, illustrating features of this category, is given:

**Case 180.\***—Molten magnesium, inadvertently spilled into the shoe of the man while at work, ignited instantaneously, ripping the shoe and burning the side and dorsum of the foot. The patient arrived at this hospital one-half hour later, where examination showed a localized, demarcated burn (Plate IA). The burned skin consisted of a white, slightly gelatinous coagulum without sensation or visible sign of circulation. Bordering the white coagulum, and in contrast to it, was a tender zone of intense pink of dilated small vessels which blanched with pressure and became pink again immediately upon release of the pressure. This zone with active circulation is seen in Plate IA along the plantar margin of the burn.

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\* The same case numbers are used in all articles on burn patients studied at this hospital under contract with the Committee on Medical Research. Numbers 1 through 39 refer to the Coconut Grove fire cases; numbers 40 through 96 to cases studied before the Coconut Grove fire; and numbers 97 through 278 to cases studied since the Coconut Grove fire.

TABLE I

CIRCUMSCRIBED FULL-THICKNESS BURNS IMMEDIATELY EXCISED AND GRAFTED

Case No. Sex Age (Yr.)	Site of Wound	Wound Extent Per Cent		Time-Hours Injury to Excision	Operative Shock and Treatment	Result Graft Take Per Cent	Reason for Failure	Time-Days Injury to Healing	Time-Days Injury to Discharge
		Total	3°						
162 F 13	Rt. foot	1	1	5	None None	99	Suture line Loss	14	18
174 M 17	Lt. wrist	1	0.5	4	None None	100		11	12
175 M 34	Scalp, neck Lt. forearm	1.5	0.5	3	None None	100 <sup>1</sup>		10	5
180 M 35	Lt. foot	1.5	1.5	6	None None	100		14	39
192 F 39	Lt. arm and hand	3	3	8	None None	95	Suture line loss	25	18
225 F 54	Lt. arm Lt. shoulder	3.5	3	53 <sup>2</sup>	None 500 cc. W. blood	75	Hematoma Poor immobili- zation <sup>3</sup> Sepsis	75	71
240 M 5	Rt. leg	1.75	1.5	4.25	None 100 cc. plasma 250 cc. W. blood	95	Suture line loss Hematoma	19	19
248 <sup>4</sup> M 62	Rt. forearm Rt. hand	10	3	11	None 500 cc. W. blood 250 cc. plasma	95	Sepsis Refrigeration of donor skin	40	47
253 F 1	Rt. forearm	3	1.5	5	None 150 cc. W. blood	95	Poor immobili- zation	48	48
276 M 60	Rt. forearm	7	1	99	None None	100		27 <sup>5</sup>	69 <sup>6</sup>
Average.....								28.3	34.6

<sup>1</sup> Wound edge approximation, no graft (Case 175).<sup>2</sup> Delayed for tissue sodium studies (Case 225).<sup>3</sup> Uncooperative, mentally retarded epileptic (Case 225).<sup>4</sup> General anesthesia not used because of burns about face and alcoholic intoxication. Delayed closure necessary because anesthesia used was inadequate for taking donor skin. At 48 hours after excision, grafts were taken but were refrigerated because excision of slough proved inadequate. At 5 days postexcision the base was not compatible with complete closure, the 3-day refrigerated grafts were laid as mosaics (Case 248).<sup>5</sup> Healing of wound delayed because of incomplete excision of full-thickness destruction at one margin (Case 276).<sup>6</sup> Discharge delayed because of burns of face including eyes (Case 276).

Aware that the skin of the dorsum of the foot is thin, the area of white coagulum was judged to be one of full-thickness destruction. Accordingly, six hours after injury the coagulum was excised under low spinal anesthesia (Plate IB). The excision was carried to the areolar tissue overlying the tendons; the areolar tissue was slightly edematous but judged not killed since the circulation was intact. The wound was closed with a split-thickness graft taken with the dermatome knife from the opposite thigh. The graft was sewn by running suture to the margin of the superficially burned skin (Plate IC). A molded, firm pressure dressing was applied. The patient was given penicillin postoperatively for 19 days. There was no clinical infection, and the take of the graft was complete (Plate ID and E). A circumscribed hematoma dissected its way into one area of the graft, but healing was not intercepted. Use of the foot was started on the 14th day. In order to prevent disruption of the newly formed vascular connections of the graft, an elastic bandage was applied whenever the foot was below the horizontal, and walking was intermittent and only gradually increased.

The burn site and extent,\* the interval from injury to closure of the

\* The total and full-thickness extents of the body surface burned are computed according to the Berkow scale.<sup>8</sup>



## FULL-THICKNESS BURN WOUNDS

wound, and the results in the ten cases with circumscribed full-thickness burns are summarized in Table I. The anesthetic and chemotherapy used, duration of operation, and bacteriologic flora encountered are given in the protocol of each case.\*\* The largest area excised and grafted was estimated to be not more than 3 per cent of the body surface. In none of the cases did the total burn, incomplete as well as full-thickness, exceed 10 per cent of the body surface. In half of the patients almost the entire area burned was full-thickness. The areas of the body affected were various; in seven cases the excision and grafting was carried out over superficial tendons of forearm, wrist, lower leg or foot, so-called critical areas. In none was the destruction deeper than the subcutaneous fascia but in all, inspection of the excised tissue left little doubt but that the skin had been completely destroyed.

The operative procedures were carried out between three and 11 hours in eight cases, but not until the 53rd and 99th hours in the other two. The 53-hour delay was necessary in an epileptic (Case 225) who was unable to cooperate; (her burn tissues were also used for radioactive sodium studies). Failure to recognize full-thickness destruction on inspection at entry accounted for the delay in the other (Case 276). Sulfadiazine was given to two patients (Cases 162 and 175) and penicillin to the remainder.

The results are judged to be gratifying and to have been better than in the succeeding categories. The grafts took at least 95 per cent except in one case, that of the epileptic not grafted until the 53rd hour, in whom there was a 25 per cent failure of the initial graft (Case 225). Delay in healing of one wound (Case 276) was occasioned not by incomplete take of the graft but by failure to excise a 0.5-cm. margin of destroyed skin at one point.

Infection developed in two cases, seriously in one, the epileptic. In this latter case, though the infection may have been influenced by the delay in grafting, it was undoubtedly influenced by inadequate immobilization of the grafted areas in an ungovernable patient.

The final healing of the grafted areas has also been pleasing; there is a minimum of scarring, keloid, contractures and disability. The hospitalization and operation disturbed but little the equanimity of the patients. The nutritional status was adequately maintained except in one patient who was a chronic alcoholic (Case 248). The psychologic outlook was good except in the epileptic. The period of hospitalization varied from 5 to 71 days, with an average of 34.6 days. One may question whether chemotherapy had a chance to play a beneficial rôle in this group of patients.

2. Circumscribed full-thickness burns in which excision and grafting were delayed constitute a second category (Table II, 11 patients with 12 wounds). A summary of one case is given as an example:

**Case 153.**—A 69-year-old, vigorous man was admitted eight days after sustaining a deep burn of the back of a leg. His greasy dungarees caught on fire while he was tending a bonfire. His wound was treated at home by his local physician and wife, a

\*\* A protocol of each patient cited in this and the other papers of this series will be published after the final paper of the series.

TABLE II  
CIRCUMSCRIBED FULL-THICKNESS BURNS—EXCISION AND GRAFTING DELAYED BECAUSE OF INVASIVE INFECTION

Case No. Sex Age (Yr.)	Site of Wound	Wound Extent			Time-Days Injury to Admission	Time-Days Admission to Excision	Type of Closure	Operative Shock and Therapy	Result Graft Take Per Cent	Reason for Failure	Time-Days Admission to Healing	Time-Days Admission to Discharge
		Per Cent Total	Per Cent 3 <sup>rd</sup>	Per Cent 5 <sup>th</sup>								
129 M 72	Lt. leg	0.5	0.5	8	8	Delayed 2 days Complete	Excision: None None Graft: None None None	100			18	31
133 F 53	Lt. thigh	2	1.5	8	4	Immediate Complete	None None	40	Inadequate immobilization Hematoma Trophic changes		97	37
151 M 78	Rt. thigh	12	2	3	6	Immediate Complete	Mild 500 cc. W. blood	95	Sepsis		48	56
152 M 52	Rt. foot	1.5	1	0	18 <sup>1</sup>	Immediate Complete	None None	100			34	55
153 M 69	Lt. thigh Lt. leg	10	9	8	4	Delayed 3 days Complete	Excision: Mild 500 cc. W. blood Graft: None 500 cc. W. blood	95	Incomplete excision Suture line loss Hematoma		47	53
154 M 50	Lt. leg Lt. foot	2	2	2	2	Delayed 2 days Complete	Excision Mild None Graft: None None <sup>2</sup>	85	Tension on grafts not optimal Sepsis		43	53
157 M 73	Rt. thigh Rt. leg	6	2.5	18	6	Delayed 2 days Complete	Excision Mild 1000 cc. W. blood Graft: None None	100			22	127 <sup>2</sup>

# FULL-THICKNESS BURN WOUNDS

TABLE II—Continued  
CIRCUMSCRIBED FULL-THICKNESS BURNS—EXCISION AND GRAFTING DELAYED BECAUSE OF INVASIVE INFECTION

Case No. Sex Age (Yr.)	Site of Wound	Wound Extent			Time-Days Injury to Admission	Time-Days Admission to Excision	Type of Closure	Operative Shock and Therapy	Result Graft Take Per Cent	Reason for Failure	Time-Days Admission to Healing	Time-Days Admission to Discharge
		Per Cent	3 <sup>rd</sup>	0.5								
159	Rt. shoulder	3.5	0.5	4	5	Delayed 4 days	Excision	Excision	0	Inadequate immobilization	40	28
M						Complete	None	None				
28							Graft	None				
							None	None				
182	Rt. arm	1.5	1	6	7	Delayed 2 days	Excision	Excision	100		22	19
M						Complete	None	None				
25						(by edge approximation)	None	None				
							Graft	None				
							None	500 cc. W. blood				
206	Lt. foot	0.5	7	7 <sup>3</sup>	Delayed 2 days	Excision	Excision	Excision	100		18	21
M		1.5			Complete	None	None	None				
68							None	None				
	Rt. foot	0.5			Delayed 2 days	Graft:	Graft:	Graft:	100		18	
					Complete	None	None	None				
							None	None				
212	Finger	2x3 cm. 2x3 cm.	7	1	Immediate	Complete	None	None	100		7	4
M							None	None				
50												
Average.....												
1 Delay in excision resulted from misjudgment at entry concerning depth of destruction. Should have been treated as patient of first category (Case 152).												
2 Delay due to infected donor sites (Case 157).												
3 Interval ordinarily would have been shorter but was prolonged for surgical treatment of carcinoma of the pharynx (Case 206).												

trained nurse, with a petrolatum gauze dressing. No chemotherapy was given. When the presence of infection was recognized he entered the hospital.

Examination on entry disclosed an infected, sloughing, deeply cracked burn covering three-quarters of the dorsum of the left leg and thigh (Plate III A and B). There was also an irregular, narrow margin of partial-thickness destruction with bleb formation. The infection was judged to be invasive because of the irregular character of the inflammation flaring out from the area of deep destruction. Cultures were taken and the patient was started on penicillin systemically.

Four days after entry, when the patient was responding well clinically to hospital care and the visible and palpable inflammation was subsiding (Plate III C and D), the area of full-thickness destruction was excised under low spinal anesthesia. The excision was carried down to the muscles and tendons and included the deep subcutaneous fascia. The wound was dressed with fine-meshed gauze overlayed by rubber tubes for local irrigation of penicillin. Thickly impregnated petrolatum gauze strips were placed over the tubes to form a pocket for the irrigating fluid and a firm outer dressing was applied. For three days the local irrigation of penicillin was added to the systemic.

On the 15th day after injury, the 7th after the start of penicillin administration and the third after excision of the dead tissue, the patient's wound was dressed in the operating room. The invasive infection had disappeared; and the wound base was free of edema and exudate (Plate III E). Firm, minute granulation tufts were appearing here and there, but otherwise the surface was formed essentially of the tissue left after excision. On this healthy base the wound was closed without drainage by placing split-thickness dermatome grafts removed from the abdomen and opposite thigh (Plate III F). The intramuscular administration of penicillin was continued for 24 more days.

The take of the grafts was almost complete. There was necrosis along the margins of an occasional suture line (Plate III G), and over an hematoma (Plate III H). Healing was delayed, however, by failure to recognize and to excise a corner of full-thickness destruction on the medial aspect of the calf (Cf. Plate III D and H). The entire wound was judged closed by the 47th day and the patient was discharged home on the 53rd day. Mobilization was slow and graded; an elastic bandage was applied for the first two months when the leg was dependent. The result has been excellent; function has been good since discharge from the hospital and there is a minimum of residual scar (Plate III I). The patient was dejected on entry to the hospital, fearing that he was going to lose his leg because of his age and the infection. His prompt recovery and subsequent usefulness of his leg have amazed him.

Review of the bacterial flora grown on cultures suggests that penicillin was effective in controlling the invasive infection and did abet the surgery. Five gram-positive organisms grew on the cultures planted on entry, a *beta* and a *gamma* streptococcus, a *Staph. aureus* and two strains of *Cl. welchii*. The first three and one of the last were demonstrated to be penicillin-sensitive *in vitro*. The *Clostridia* disappeared and *E. coli* appeared before excision; the staphylococcus disappeared after excision of the slough.

The observations on the 11 patients of this category (circumscribed full-thickness burns in which excision and grafting were delayed) are summarized in Table II. The details of anesthesia, duration of operation, bacterial flora and chemotherapy are given in the protocols. The areas excised and grafted varied from 2 x 3 cm. to 9 per cent of the body surface, with the total area burned varying from 2 x 3 cm. to 12 per cent. The full-thickness burns included various body areas and, as in the first group, destroyed the subcutaneous fascia but not the deeper tissues. The reason for the delay in excision and grafting in all cases was the presence of active invasive infection. Only one of the cases was admitted on the day of the burn, and the burn of this patient



COLOR PLATES

PLATE IA.—Case 180: The left foot of a 35-year-old man one hour after a burn from molten magnesium. Visible circulation and sensation were absent throughout the white area; full-thickness destruction of the skin was judged to have occurred since the skin in this area is thin. The intact circulation of the adjoining thick plantar skin is shown in the photograph as a rim of intense red. This red zone was hypersensitive.

B.—Case 180: The same site six hours after injury during excision of the white skin assumed to have been fully destroyed. The distal half of the dead skin has already been excised. There was slight edema of the subcutaneous areolar tissue. A tourniquet was not used. The few bleeding points were snapped and tied with silk.

C.—Case 180: The operation completed. The wound left after excision of the dead skin has been closed with a split-thickness graft removed from the opposite thigh.

D.—Case 180: The wound seven days after injury and excision and grafting. There has been a complete take of the graft. Blood, presumably from an unsecured vessel, has dissected its way into the midportion of the graft, discoloring but not preventing the healing of the graft.

E.—Case 180: The wound 44 days after injury and closure. There is slight keloid formation along the margins and in the center of the graft where the hematoma formed.

PLATE IIA.—Case 149: Both legs and thighs of a 20-year-old male two hours after sustaining a burn of 72 per cent of the body surface. The skin of the lower legs was firm, white, avascular, asensitive and denuded in part of epidermis; that of the posterior aspect of the thighs was parchment-like. The skin of these areas was considered to have been fully destroyed. The circulation of the skin over both knees was intact and the skin was judged to have been incompletely damaged.

B.—Case 149: Both legs and thighs from the left side on the day of injury. The left leg was judged to have received more extensive full-thickness destruction and was selected for surgical care on the 7th day. It was wrapped in petrolatum gauze without débridement. (The right leg was wrapped in pyruvic acid paste.)

C.—Case 149: Medial aspect of the left leg seven days after injury and immediately before surgical excision of the slough and grafting.

D.—Case 149: Medial aspect of left leg during excision of the dead skin. The vital skin around the knee with intact circulation is being saved. No tourniquet is being used.

E.—Case 149: Medial aspect of left leg immediately following closure with a stocking of split-thickness grafts removed from the anterior chest and abdomen, the only unburned portions of the body.

A



B



C



D



E



PLATE I

A



B



C



D



E

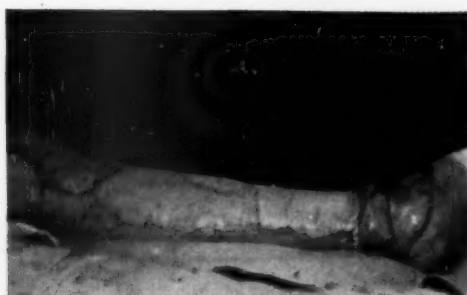


PLATE II

PLATE II F.—Case 149: Lateral aspect of the left leg seven days after injury and immediately before surgical excision of the slough and grafting.

G.—Case 149: The popliteal space and posterior aspect of left thigh on the 7th day and prior to excision and grafting.

H.—Case 149: The line of excision of the dead skin on the outer aspect of the left ankle.

I.—Case 149: Excision of the slough of the left leg completed. No tourniquet used.

J.—Case 149: Left leg. Closure of the wound left after excision of slough has been completed by a stocking of grafts.

K.—Case 149: The left leg on the 17th day after grafting, the 24th after injury. There was pressure necrosis around the malleoli and along a few suture lines, otherwise the take of the graft was satisfactory.

L.—Case 149: Posterior aspect of thighs and right leg on the 47th day after injury when postage stamp grafts were placed on the wound areas the slough of which was left to separate spontaneously (left thigh) and with the help of pyruvic acid paste (right thigh and leg).

M.—Case 149: The left leg on the 61st day after grafting, the 68th after injury.

N.—Case 149: The left popliteal space and thigh on the 68th day after injury, failing to reveal at this stage any better healing of the stocking graft which was placed on the excised base than of the later postage-stamp grafts which were placed on the granulating surface.

O.—Case 149: Both legs on the 97th day after injury. Keloid scar has formed diffusely beneath the grafts laid on granulation tissue; contracture is apparent in the popliteal space. In contrast, there is no keloid scarring, except along the suture lines, of the sheet grafts which were laid on the base left after excision; there is no contracture in the popliteal space.



F



K



G



L



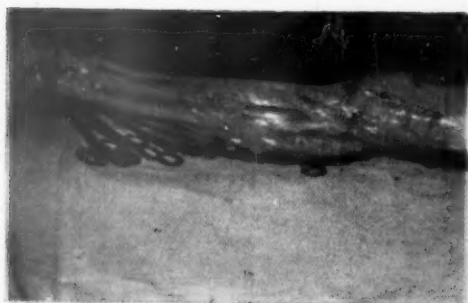
H



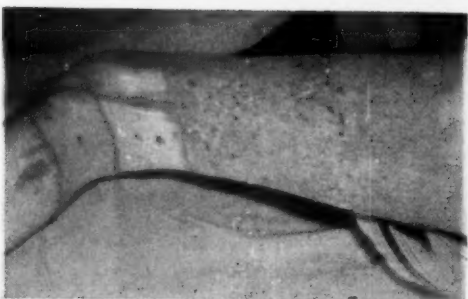
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I



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J



O



PLATE IIIA.—Case 153: Lateral aspect of the left leg of a 69-year-old man on admission to hospital, eight days after injury. The burn, from greasy trousers ignited by a bonfire, had been treated at home with a petrolatum gauze dressing and no chemotherapy. The inflamed irregular border surrounding the deep burn suggested invasive infection.

B.—Case 153: Medial aspect of left leg on day of admission, 8th after injury. The deep infected slough over the calf and popliteal space is to be contrasted with the more anterior incomplete-thickness burn with blebbing.

C.—Case 153: Lateral aspect of left leg on 12th day after injury, 4th day after admission and start of penicillin. The deep burn is more clearly demarcated and the invasive inflammation has decreased.

D.—Case 153: Medial aspect of left leg on 12th day after injury, 4th day after admission and start of penicillin and just before the deep slough was excised.

E.—Case 153: Lateral aspect of left leg on 15th day after injury, 7th after admission and start of penicillin and 3rd after excision of the slough. The tendinous fascia overlying the calf muscles is exposed. All evidence of invasive infection has disappeared. The wound was closed with grafts immediately after this photograph was taken.

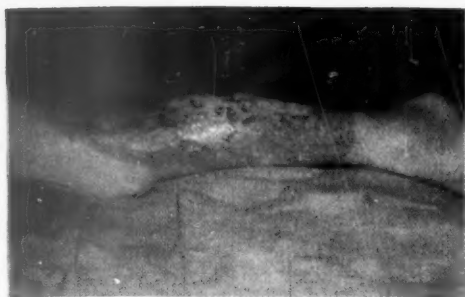
F.—Case 153: Medial aspect of left leg immediately following closure of wound with split-thickness grafts on the 15th day after injury, 7th after admission and start of penicillin and 3rd after surgical excision of the slough. An area of doubtful thickness which was not excised is visible in the angle of the wound in the center of this figure.

G.—Case 153: Lateral aspect of left leg on the 7th day after grafting, the 22nd after injury. Except for loss at a few points along the suture line and over a small hematoma, the take of the grafts is complete.

H.—Case 153: Medial aspect of left leg on the 14th day after grafting, the 29th after injury. The failure of the take of the graft caused by the hematoma in the popliteal space and the line of demarcation of the area of questionable full-thickness destruction, which was not excised, are visible.

I.—Case 153: Follow-up of the left leg two years after injury. There is a minimum of scarring and no disability. The grafted skin of the popliteal space was pinched to demonstrate its flexibility.

A



B



C



D



E



F



G



H



I

### PLATE III

NOTE: As the lettering on Plate III as printed in the paper by Drs. Cope, Langohr, Moore and Webster in the ANNALS OF SURGERY for January, 1947, was incorrect, this corrected plate has been prepared with gummed edges for insertion in its place.

A



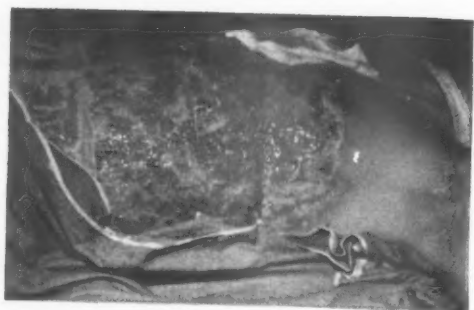
F



B



G



C



H



D



I



E



J



PLATE IV



## FULL-THICKNESS BURN WOUNDS

was not immediately excised and grafted because the depth of injury was misjudged on entry to be of only partial skin thickness. The other patients were admitted from two to 18 days after injury.

Because invasive sepsis in all wounds was present at the time excision of the slough was contemplated, chemotherapy in all and delayed closure in the majority were resorted to. Penicillin, either parenterally or locally, was used in all cases, and accompanied by sulfadiazine in two cases (Cases 159 and 206) and tyrothricin in three cases (Cases 152, 153 and 157). A subsidence of the inflammatory reaction was observed in almost all wounds prior to the excision. In four cases the wound was closed immediately following excision. In the other nine an interval of from two to four days was allowed to elapse between excision and closure. In all cases closure was complete. To the excised, ungrafted wounds of the nine cases with delayed closure, penicillin was applied locally.

The results were surprisingly successful. In nine wounds the take of the grafts was virtually complete, a result comparable to the best in the patients of the first category. In the remaining three wounds the takes of the grafts were zero, 40 and 85 per cent. Inadequate tension and immobilization are believed to have accounted for lack of success in the first two of these, and sepsis in the third.

Owing to the clinical observation that the inflammation which was present prior to excision of the burn slough subsided during the parenteral adminis-

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PLATE IV A.—Case 135: The right side of the trunk of a 16-year-old girl on entry two hours after a burn from an explosion of a gas stove. The deepest injury, a broad band of parchment-like skin, was outlined by her brassiere.

B.—Case 135: The left side of the trunk at entry. The parchment-like skin extended to the posterior axillary line. The wounds were dressed with petrolatum gauze, without débridement or cleansing. Excision and grafting were planned for the 7th day. Penicillin was started.

C.—Case 135: The slough on chest and abdomen on the 7th day, immediately before the initial excision and grafting. The bluish tint of the slough is from the blue dye, T-1824, used for the plasma volume determinations.

D.—Case 135: The right side and back of the chest on the 7th day, immediately before the initial excision and grafting.

E.—Case 135: The right side of the chest immediately following surgical excision of the slough and closure of the wound with split-thickness grafts. The excision was carried into edematous fat, on which base the grafts were laid.

F.—Case 135: The right side of the chest on the 7th day after excision and grafting, the 14th day after injury. There is sloughing above the suture over the right breast where the excision was incomplete. There are numerous small hematomas in the graft. The take of the graft, however, is complete.

G.—Case 135: The left and unexcised side of the chest on the 14th day after burning. The slough has already separated spontaneously over wide areas; nongranulating inflamed fat is exposed. The wound was excised immediately following the taking of this photograph and a wet penicillin pack dressing applied.

H.—Case 135: The left side of the chest on the 4th day after excision, the 18th after injury. In spite of the inflamed appearance of the base, split-thickness grafts were laid upon it, and the wound closed.

I.—Case 135: The left side of the chest immediately after closure with grafts on the 18th day after injury. The new grafts were sewed to those placed 11 days previously.

J.—Case 135: The left side of the chest on the 7th day after grafting, the 30th after injury. In contrast to the successful take of the grafts on the right side which were placed on the 7th day after injury, the take of these grafts, laid upon an inflammatory base on the 18th day after injury, did not exceed 55 per cent.

tration of chemotherapy, it is hard to escape the conclusion that chemotherapy helped in the successful outcome.

Review of the bacteriologic findings of this group yields evidence that penicillin may have been more effective in certain cases. *B. coli* and *B. proteus* were recovered only from the wounds which did not heal promptly. The recovery of five organisms, all gram-positive, and four penicillin-sensitive *in vitro*, in the case with the most extensive wound in this category, has already been cited in the case report.

The final outcome of the grafting has been varied. Some grafts are excellent, with minimal scarring and producing no disability, while other wounds have formed keloid. It is an impression that the keloid and scarring are roughly proportionate to the amount of the preëxisting infection.

No difficulty in the control of fluid and electrolyte balances or nutrition was encountered in these patients. The dejected psychologic state of some on entry was readily overcome by the promptness of the therapy. The period of hospitalization varied from 4 to 127 days (average 44 days). The time from admission to healing averaged 34.5 days.

3. Extensive full-thickness burns of recent origin constitute the third category in which surgical excision and grafting have been carried out. Thirty wound areas in 17 patients of this category have been so treated.

As an example of the perplexities which may be encountered and the benefits to be derived from prompt therapy, a brief outline is given of the management of the most extensively burned patient of this group in whom early closure was undertaken:

**Case 149.**—The patient was the driver of a full gasoline truck which, when forced off the road, overturned, caught on fire and exploded. He was extricated by passers-by from the burning cab and thrown into a nearby stream to extinguish his flaming clothing, but not before he had been severely burned. At the community hospital he was given morphine and reached this hospital by ambulance two hours after injury. On entry, it was estimated that 72 per cent of his body surface was burned, 38 per cent of the total surface being full-thickness. The deeper portions were charred and leathery; those of the forehead, ears, upper face, lower neck and over the manubrium, backs of both hands, both lower legs and the backs of both thighs were considered to be full-thickness, while those of the lower back and buttocks, even though tanned, were of questionable depth. The only unburned portions of the body were the lower anterior chest and abdomen.

It was decided to treat the full-thickness burns of one leg by surgical excision and grafting on the 7th day, the wounds to be covered in the meantime with a petrolatum gauze dressing without any débridement or cleansing, and the patient to be given penicillin intramuscularly; pyruvic acid paste, according to the method of Connor and Harvey, was to be applied to the wounds of the other leg. The right leg, the less severely burned of the two (Plate II A and B) was chosen for the pyruvic acid method.

Reasonable homeostasis was achieved and maintained by massive volumes of plasma, saline solution, whole blood and a high protein diet. The details of this therapy are given in the protocol and discussed in later papers under "Disordered Physiology."<sup>2</sup> Edema of the larynx developed and necessitated tracheotomy at the 30th hour.

Because physiologic equilibrium of the patient and undisturbed renal function were achieved, the operative program could be adhered to. It was hoped that his despondency over his disfigurement would be dissipated by the promise of early healing. On the 7th

## FULL-THICKNESS BURN WOUNDS

day, under intravenous pentothal anesthesia, split-thickness grafts were removed with the dermatome from the entire unburned surface of the anterior chest and abdomen by one operating team while a second team excised the dead hide of the left leg from the ankle to above the popliteal space. Only that amount of full-thickness destruction (12 per cent of the body surface) was excised which could be covered by grafts from the unburned skin available. It was recognized that more of the left thigh would have to be grafted at a later date when skin was again ripe. The wound left after excision was closed by a stocking of grafts and without drainage. Plate II C through J shows the appearance of the necrotic skin before and during excision, the depth of the excision, the nature of the base upon which the grafts were placed and the wound after closure.

The take of the grafts was marred only by pressure necrosis behind the malleoli and Achilles tendon due to a faulty dressing (Plate II K). Separation of the slough of the right leg under the pyruvic acid paste was not prompt (perhaps due to faulty technic of application) and the wounds of this leg and the back of the left thigh were eventually covered on the 47th day by placing mosaic grafts on granulation tissue (Plate II L). The other areas of full-thickness destruction, forehead, face, dorsum of hands and fingers, were also covered by placing grafts on granulations following spontaneous separation of the slough. Each area was grafted as soon as the granulations appeared firm.

The patient responded to the aggressive therapy with excellent morale. He was discharged home, with all wounds closed, on the 85th day after injury and returned to work six weeks after leaving the hospital, or 15 weeks after injury. Cataracts were discernible in both eyes six months after injury, but they have not progressed to the extent of preventing continuous employment.

Follow-up examination showed that the grafts which were laid immediately upon the base left after excision of the slough healed with less scarring and greater mobility than those placed upon fibrous tissue granulations (Plate II M, N and O).

The observations and operations on the 17 patients of this category (recent extensive full-thickness burns) are summarized in Table III. The details of shock and chemotherapy, bacteriology, anesthesia, duration of operation, blood loss, and metabolic observations are given in the protocols, and in many cases also in the articles on bacteriology and disordered physiology.<sup>2</sup>

The area of full-thickness burns in these patients varied from 1 to 38 per cent and the total burn from 5 to 72 per cent of the body surface. Four of the patients, of whom two were children, had a total burn of less than 10 per cent; they are included in this category of extensive burns because homeostasis was sufficiently disturbed to require postponement of operation. The largest wound area excised and grafted at any one operation was 12 per cent. In some of the wounds in this group, deep structures were burned. The wounds were located in all areas of the body.

The interval between injury and initial operation varied from 1 to 35 days. In some the interval was conditioned by the continued physiologic imbalance of the patient. It was arbitrarily set in many cases on entry in order to explore the usefulness of penicillin in holding infection in the wounds in abeyance, and is longer than would now be practiced. Penicillin was administered intramuscularly from the time of entry to all patients, and locally on some wounds after excision. Sulfamerazine had been given to one patient prior to entry to this hospital (Case 170), otherwise no chemotherapeutic agent other than penicillin was used.

In one-half of the wound areas the grafting was 95 per cent, or more, successful. A few of the wounds excised and grafted after two weeks fall into this excellent group but, in general, the success of grafting diminished with the lengthening of the interval between injury and operation. In all of the areas where grafting failed there were signs of active infection, and the majority of the failures in the group are, therefore, attributed to sepsis. In two of these unsuccessful areas the excision had not been carried deep enough; it is believed that the residual necrotic tissue nourished the infection and prevented the blood supply from succouring the graft.

The decreasing success of grafting with an increasing interval between injury and excision and grafting is impressive; a case from this category of extensively burned patients is cited to illustrate this point:

**Case 135.**—A 16-year-old girl reached this hospital two hours after her clothes had been ignited by a blast from a gas stove. The front and right side of the trunk and both arms were burned, areas comprising approximately 25 per cent of the body surface. The major portion of the burn was deep. This was believed due to the intensity with which the material of her brassiere burned, for from just to the right of the midline in the back around front to the midaxillary line on the left was a broad, white parchment-like outline of the garment (Plate IV A and B). The lower half of each nipple and of the skin of each breast was included in the parchment-like area. There was also a smaller, irregular zone of white skin on the left side of the abdomen.

The areas of white parchment-like skin were considered to be of full-thickness destruction because visible circulation and sensation were absent. Excision and grafting were planned for the 7th day; the wounds were wrapped in a petrolatum gauze dressing, with no débridement or cleansing, and penicillin was started intramuscularly. Homeostasis was reestablished and held by maintaining a measured, normal circulating blood volume and renal output. On the 7th day the dressings were removed in the operating room. The initial impression of what constituted full-thickness destruction was confirmed; the necrotic tissue was more moist than on entry but no spontaneous separation was yet apparent (Plate IV C and D). Under gas-oxygen-ether anesthesia, the full-thickness portion of the wound of the right side of the chest was excised. The excision was carried into edematous fat; so edematous was the fat posteriorly that small pools of fluid were cut through. On this base were placed six sheets of split-thickness skin removed with the dermatome from the thighs. The wound was closed without drainage by sewing the sheets together and to the borders of the excised wound. The border was made up of the full-thickness slough medially, and elsewhere, of healing second-degree burn (Plate IV E).

On the 7th day after grafting (14th day after injury) the dressings were removed. The take of the grafts was perfect, including those along the margin of the full-thickness burn in the anterior midline. There was slight separation superiorly where the nipple areola and an unexcised margin of skin on the breast had sloughed. Damaged, but doubtful, full-thickness nipple tissue had not been excised on the chance that it might survive (Plate IV F). Spontaneous separation of the unexcised slough on the left side had already started (Plate IV G).

At this second exposure of the wound (14th day after injury) the full-thickness wound of the left side of the chest was excised. In contrast to the edematous fat uncovered seven days previously on the right side, the subcutaneous fat was now inflammatory. It was thickened, stiff, nonwatery, and vascular. In view of this inflammation, presumably infectious in origin, it was decided not to graft immediately but to treat expectantly with a gauze pack and local penicillin in addition to the systemic penicillin. On the 4th day after excision (18th day after injury) the appearance of the base left after excision had



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not significantly changed (Plate IV H). In spite of the slight but deep inflammatory reaction, the area was grafted (Plate IV I). The take of the graft, unlike that of the grafting done on the 7th day, was little more than 50 per cent successful.

Undoubtedly, there were factors other than the slowly progressive infectious inflammation beneath the burn of full-thickness which contributed to the partial failure of the take of the 18th day grafting as compared with complete success of the 7th day grafting. The patient had become uncoöperative, had scratched under the dressing, and had torn the grafts near the midline. She was also not eating well and was at the peak of her metabolic and nutritional imbalance. But the presence of all these factors, in addition to progressive sepsis in such a burn wound, only serves to emphasize the importance of closing any full-thickness burn wound immediately.

Clinical signs of infection were encountered in all of the wounds of this category prior to excision, the administration of penicillin, notwithstanding. In one patient the burns of the legs were so deep that tendons and muscles were necrosed, gas gangrene developed and bilateral amputation was necessary.

The final outcome of the grafts has varied considerably. Deep scarring and contractures have formed in those wounds where there was prolonged infection. Good healing, with minimal scar and keloid formation, has taken place in those wounds which were grafted in the first week after injury.

In the care of all of the patients of this category it was necessary to be vigilant concerning burn shock. In some the period of impending shock passed without incident, in others the control of the electrolyte, fluid and plasma colloid balances was not achieved until several days after admission. In many the adaptation to traumatic insult, protein deficit and malnutrition plagued us. In those patients in whom recovery was prompt the initial discouragement was dissipated. The period from injury to discharge from the hospital varied from 22 to 223 days, the average being 87 days (Table III). If the child whose unhealed donor site delayed discharge until the 223rd day is omitted (Case 137), the average becomes 79 days.

### TECHNICAL CONSIDERATIONS

The plan of immediate excision and grafting of a full-thickness burn wound will be marred if the surgeon does not appreciate the importance of (1) the assessment of the depth of destruction; (2) chemotherapy as an adjunct; (3) certain details of operative technic (anesthesia, control of hemorrhage, width and depth of excision and the condition of the grafting base); and (4) homeostasis.

1. *Assessment of the Depth of Destruction.*—The surgeon must distinguish the depth of destruction when the patient is first seen in order to treat the full-thickness wounds expeditiously. If the wounds have already been dressed when the patient is seen by the responsible surgeon, the dressings will have to be removed or the surgeon will be blind in his treatment of the wounds and the patient.

The gross appearance of the skin, the state of the circulation and sensation and the position of the burn offer clues for evaluation of the depth of destruction. Charred, tanned, leathery or white, coagulated skin indicates deep destruction. Also, in deeply damaged skin the visible circulation in the small



TABLE III  
EXTENSIVE FULL-THICKNESS BURNS EXCISED AND GRAFTED

Case No. Sex Age (Yr.)	Wound Extent Per Cent		Site of Wound	Extent of Excision Per Cent	Time-Days Injury to Excision	Type of Closure	Operative Shock and Treatment		Result Graft Take Per Cent	Reason for Failure	Time-Days Injury to Healing		Time-Days Injury to Discharge
	Total	3°					Moderate	Excision:			Poor immobilization	34	
135 F	25	15	Rt. chest Rt. back	9	7	Immediate Complete	1000 cc. W. blood	Excision: Mild	95	Poor immobilization Suture line loss	34	92	92
16			Lt. chest Upper abdomen	6	14	Delayed 4 days Complete	Excision: Mild 1000 cc. W. blood	Excision: Mild	50	Poor immobilization Sepsis	92		
137 M 6	8	6	Rt. leg	6	6	Delayed 2 days Complete	Excision: None None Graft: Mild 800 cc. W. blood	Excision: None None Graft: Mild 500 cc. W. blood	65	Incomplete excision Inordinate pressure Sepsis	89	223 <sup>1</sup>	
142 M 52	8	1.5	Lt. lat. ankle	0.5	8	Immediate Complete "dermal"	Moderate 500 cc. W. blood	Moderate 500 cc. W. blood	25	Sepsis Hematoma Type of graft	46		
			Lt. lat. calf	0.5		Immediate Complete "epidermal"			85	Sepsis Suture line loss	30		
			Lt. patella	3/4		Delayed 7 days Complete			80	Sepsis	37	123	
			Lt. inf. patella	3/4	15	Immediate Complete	None 1000 cc. W. blood	None 1000 cc. W. blood	15	Sepsis	60		
			Lt. med. ankle	0.25		Immediate Complete			10	Sepsis	46		
143 M 17	40	34	Ant. rt. thigh	4	11	Delayed 8 days Complete	Excision: Mild 1000 cc. W. blood	Excision: Mild 1000 cc. W. blood	100		32		
			Lt. leg	2	11	Delayed 4 days Complete	1st stage grafting: None	1st stage grafting: None	95	Graft overlay bone sequestrum	77	122	
				3		Delayed 22 days Complete	500 cc. W. blood 2nd stage grafting: Mild 500 cc. W. blood 3rd stage grafting: Severe Op. discont. 1000 cc. W. blood 250 cc. plasma	500 cc. W. blood 2nd stage grafting: Mild 500 cc. W. blood 3rd stage grafting: Severe Op. discont. 1000 cc. W. blood 250 cc. plasma	80	Hematoma Sepsis	77		

## FULL-THICKNESS BURN WOUNDS

TABLE III—Continued  
EXTENSIVE FULL-THICKNESS BURNS EXCISED AND GRAFTED

Case No.	Wound Extent		Site of Wound	Extent of Excision Per Cent	Time-Days Injury to Excision	Type of Closure	Operative Shock and Treatment	Result Graft Take Per Cent	Reason for Failure	Time-Days Injury to Healing	Time-Days Injury to Discharge
	Sex	Per Cent									
Age (Yr.)		Total	3°								
149	M	72	38		7	Immediate Complete	Mild 1000 cc. W. blood	95	Inordinate pressure	54	85
20											
155	M	41	26		8	Immediate Complete	Mild 1000 cc. W. blood	75	Tension Sepsis	41	
48					9	85% delayed 10 days Complete 15% delayed 30 days Incomplete	Excision: Moderate 1000 cc. W. blood 1st grafting: Severe. (Op. discont.) 1000 cc. W. blood 2nd grafting: None	100		62	108
					21	Delayed 14 days Incomplete (Refrig. grafts 14 days)	None 3rd grafting: None	100		62	
161	M	12	7		7	Immediate Complete	Mild 1000 cc. W. blood	80	Poor immobilization Sepsis	53	60
69											
164	M	36	7		6.5	Immediate Complete	Moderate 500 cc. W. blood	60	Suture line loss Sepsis	48	60
32											
166	F	17.5	7.5		4	Immediate Complete	None 1000 cc. W. blood	60	Proteolytic sepsis	68	70
30					2.5	Delayed 2 days Complete	Excision: None 1000 cc. W. blood Graft. Mild 1000 cc. W. blood	95	Hematoma Suture line loss	Unhealed 70	
170	M	15	13		3.5	65-70% Immediate	Excision & 1st grafting: Marked (Op. discont.)	70	Sepsis	29	

TABLE III—Continued  
EXTENSIVE FULL-THICKNESS BURNS EXCISED AND GRAFTED

Case No.	Wound Extent		Site of Wound	Extent of Excision Per Cent	Time-Days Injury to Excision	Type of Closure	Operative Shock and Treatment		Result Graft Take Per Cent	Reason for Failure	Time-Days Injury to Healing	Time-Days Injury to Discharge
	Total	3°					1000 cc. W. blood	2nd grafting:				
Age (Yr.)	42				9	Complete						74
			Lt. arm	2		Delayed 9 days Complete			95	Hematoma Suture line loss	66	
196	15	1	Rt. wrist	1	4	Immediate Complete	None	1000 cc. W. blood	98	Suture line loss	13	22
M							None					
51												
210	31	25	Rt. arm	3	8	Delayed 13 days Incomplete	Excision: Marked (Op. discont.)		100		120	
F			Rt. shoulder									
34			Rt. chest	1.5	8	Delayed 13 days Incomplete	1500 cc. W. blood 500 cc. plasma Grafting: Mild		100		102	128
							1000 cc. W. blood					
218	18	2	Rt. foot	0.25	14	Delayed 3 days Complete	Excision: None		0	Sepsis	62	
M							None					
54							None					
			Lt. foot	0.25	14	Delayed 15 days Complete	1st grafting: None None 2nd grafting: None		60	Sepsis	103	114
229	9	7	Rt. shoulder	3.5	31.5 (hrs.)	Immediate Complete	None		85	Inadequate immobilization Sepsis	54	64
F			Rt. breast				1000 cc. W. blood 500 cc. plasma					
28												
254	45	5	Rt. thigh	0.5	35	Immediate Complete	None		98	Suture line loss	42	64
M							1500 cc. 5% D/W					
38												
258	5	1	Lt. shoulder	2x3 cm. 3x4 cm.	19	Immediate Complete	None		100		26	28
M							None					
60												
277	12	11	Rt. leg	11	1	Delayed 2 & 6 days Complete	Excision: None		98		38	45
M							250 cc. W. blood 250 cc. plasma 1st grafting: None					
6							250 cc. W. blood 2nd grafting: None					
							250 cc. W. blood					
Average.....												57.8
Discharge delayed by infected donor sites and persistence of the malnutrition present on entry (Case 137).												87

## FULL-THICKNESS BURN WOUNDS

vessels is obliterated. Sometimes blood coagulated within the superficial vessels gives the appearance of active circulation but pressure fails to dislodge the pigment. In an incomplete-thickness burn wound with intact circulation not only is the pink color displaced with pressure but the flush returns instantaneously with release of the pressure, so open is the arterial bed.

Sensation is lost if destruction of the skin is complete. Superficial and deep incomplete-thickness burns are usually exquisitely tender except in relatively insensitive areas of the body, such as the buttocks and upper thighs. Careful testing for loss of sensation should be made in all burned areas which are suspected of being of full-thickness.

The location of the burn should be taken into consideration when assessing the depth of skin destruction. Where the skin is normally thin and hair follicles do not extend far beneath the derma, as over the dorsum of the hands and feet, the anterior surface of the wrists, the malar bones of the face and around the eyes, minimal coagulation represents full-thickness destruction. In contrast, charred or leathery skin, without either sensation or visible circulation, does not necessarily indicate full-thickness destruction when it lies over the buttocks, sacral portion of the back, upper portion of the back of the thighs, and in the male over the chin, upper lips and cheeks. The skin of the buttocks, upper thighs and lower back is thick and tough; the hair follicles of the male beard extend well-beneath the derma.

No objective method of determining the depth of destruction of a burn has proven of aid to us. Among other methods we have tried the fluorescent ultra-violet lamp, as suggested by Dingwall<sup>9</sup> but since it depends upon the presence of the circulation of the blood at a visible level, it has proved no more useful in our hands than the naked eye.

In practice, any quandary over the depth of destruction can be resolved. In a patient with a burn of limited extent, where there is any doubt as to the depth of destruction, it is wise to err by exaggerating rather than depreciating the depth. If the burn is sufficiently deep to be under consideration as one of full-thickness, much time and disability will be saved by excising and grafting it immediately as a full-thickness burn wound. If one waits for the depth to become distinct, the temporizing may tempt the infection and the auspicious moment for getting the wound healed may be lost. Deep incomplete burns, like those of true full-thickness, are so susceptible to infection if the slough is left that much fibrous tissue proliferation in the derma and ugly and disabling scarring will form with spontaneous healing. The condition of the patient with a burn of limited extent should be such to enable him to stand the operation.

In a patient with extensive burns, some of which are of doubtful full-thickness destruction, it is best to depreciate rather than exaggerate the depth of these areas. They will have to be treated, temporarily at least, as of partial-thickness destruction while the veritable full-thickness areas are excised and grafted since the condition of the patient will be such as to enable him to stand just so much surgery and there will be only a meager amount of skin which will be unburned and available for use in grafting. By the time any doubtful

areas prove themselves to be of full-thickness destruction, the condition of the patient should be such as to enable him to stand further surgery, and more healed skin will be available for use in grafting.

2. *Chemotherapy as a Surgical Adjunct.*—Our appraisal of the value of the chemotherapeutic agents, the sulfonamides and penicillin, as adjuncts to the surgical management of full-thickness burn wounds is the result of a clinical impression and a statistical analysis of the bacterial flora cultured. The effect of these agents upon the bacterial flora will be described in a subsequent paper.<sup>2</sup>

In the partial-thickness burn wound of the skin with blebbing, it was possible to prove free permeation of the sulfonamides into the wound by analyzing the bleb fluid periodically. For as late as five days after injury the concentration of sulfadiazine rose as rapidly in the bleb fluid as in the blood serum following oral administration of the drug.<sup>10</sup> It has not been possible to make such an objective study of the full-thickness wound. The blue dye, T-1824, given intravenously is seen to pass rapidly, within ten minutes, into wounds of partial-thickness but only slowly into deep burns, and then it is found only in the base of the wound. Even after several days the dye has not penetrated far enough through the slough to show at the surface. This dye combines rapidly with the albumin of the serum<sup>11</sup> and its passage in the coagulum may well be retarded by the protein. Ionic radioactive sodium, however, requires many hours to enter the burn slough. (The details of the radioactive sodium studies are recounted in a subsequent paper.<sup>2</sup>) There is indirect bacteriologic evidence suggesting that penicillin does not penetrate the necrotic tissue. Even after prolonged penicillin therapy of high dosage (one to two weeks of 500,000 units per day), the excised slough has been found to contain the same penicillin-sensitive organisms recovered by smear culture at entry. After excision of the slough it has been found possible to eliminate effectively the streptococcus and sometimes the staphylococcus.

From the evidence available, it is suspected that chemotherapeutic agents do not permeate the full-thickness wound to a level comparable to that in the fluid of the partial-thickness wound. Although in neither wound are we sure that the agent enters the damaged cell, in the partial-thickness wound it is in the extracellular space in a therapeutic concentration and may serve to abort the growth of infecting organisms.

Clinical experience bears out the assumption of this difference between the partial- and full-thickness wounds. Infection has proven amenable to control in the partial-thickness wound but ungoverned in the full-thickness. As already stated, all of our full-thickness wounds which were not excised in the first days after inception have become infected in spite of the systemic administration of penicillin or the sulfonamides.

The high incidence of infection in the unexcised full-thickness wound does not mean, however, that penicillin, or the sulfonamides, are without beneficial effect and of no use. The prompt subsidence of invasive infection once penicillin was started in many of the cases in which chemotherapy had been withheld, and the absence of invasive infection in most of the cases in which peni-



cillin was started immediately following injury, indicate that this drug is a valuable adjunct to the surgical management of the deep-burn wound. Only in the cases where the contaminating organisms were not amenable to penicillin or where the depth of tissue destruction was such to damage the blood supply to the limb was invasive infection wholly uncontrolled.

3. *Operative Technic.—Anesthesia:* There is nothing peculiar to burn trauma which has influenced our choice of an anesthetic agent. A normal circulating blood volume and proven normal renal output have been requisites before any anesthetic has been administered. Gas-oxygen-ether, spinal procaine or pantocaine and intravenous pentothal have each been used. In patients with burns of the head and neck we have respected laryngeal edema and have insured an adequate air-way by using an intratracheal tube when administering a general anesthetic.

*Control of Hemorrhage:* During excision of the burn wound, control of hemorrhage has been arduous. If the excision is carried out in the first 48 hours, during the period of the development of edema, the bleeding is localized to a few arteries which can be easily tied. The edema may persist through the first week but later an inflammatory reaction, presumably the result of spreading infection, develops beneath the burn slough. Where the line of excision is carried into this inflammation, bleeding is profuse, there being many actively bleeding vessels. If the wound is extensive, large volumes of whole blood (as much as 1,750 cc.) may be lost at the time of the excision. It may be impossible to tie all of the small bleeders and control of the hemorrhage is achieved only by prolonged pressure.

In spite of meticulous hemostasis of the excised base immediately before laying the grafts and of applying a pressure dressing over the grafts, an occasional small hematoma has formed. Blood has dissected superficially into the graft, encouraged by the pressure holding the graft in place. Surprisingly, the hematomas have not prevented the successful take of the grafts and have only resulted in transient discoloration.

*Width and Depth of Excision:* In the excision of full-thickness burn wounds we have committed two technical errors. Failure to excise widely enough has occasioned delay in healing in three patients. We were too conservative in our interpretation of full-thickness destruction. We failed to excise small portions of the wound immediately adjacent to what was known to be full-thickness. Following spontaneous separation of the slough, additional grafts had to be placed to close the wound. In all three cases a little more radical excision could readily have been accomplished.

Failure to excise deeply enough made a secondary grafting procedure necessary in two patients and jeopardized the life of a third because gas gangrene developed in necrotic tissue in two legs not amputated when they should have been. In the first two cases the slough overlay the ankle and there was fear of damaging the tendons to the foot; an adequate excision would have avoided a granulating wound. In the third instance the necrosis involved tendons, muscles and the periosteum of the tibia, and although this deep

necrosis was recognized at the time of excision, we, unwisely, awaited spontaneous demarcation. The development of frank gas gangrene settled the question—débridement was carried out by amputation of both legs.

*Grafting Base:* The best base upon which to lay grafts is the one left after excision during the first hours after injury. This base may be made up of fatty or areolar tissue, fascia, muscle or periosteum. Even if the base is grossly edematous and exuding water, grafts may be laid directly on it with impunity. The grafts will not take, however, if a thin layer of dead tissue is left, that is, if the excision is not deep enough, or if the base is inflammatory. The longer the delay before excision the greater will be the inflammation.

4. *Homeostasis.*—Homeostasis is precarious in any patient with burns of more than limited extent and it must be effected and maintained not only, as always, to keep the patient alive but also to permit him to go through the surgery required to close his deep wounds promptly and to be in such good condition that his grafted skin will heal. The progress made in achieving homeostasis will be recounted in detail in subsequent papers.<sup>2</sup> Although the problem of achieving homeostasis early has been made more complicated by the operating attending early excision and grafting, this is more than compensated for later on by the elimination of infection, effecting good nutrition and early healing. We have tried staged operations, thinking that a number of short procedures rather than one long one would prove less insulting. We have no proof that this is generally effective.

*DISCUSSION.*—It is an extraordinary commentary on the passivity of the surgeon that he has been sitting on the sidelines for so many years watching the full-thickness burn wound degenerate into a bacterial quagmire when the means of healing it promptly by excision and grafting, a simple practice of his art, were at hand.‡ Are there any extenuating circumstances for his passivity? We cannot accept a fear of unseating homeostasis by an operation or the lack of chemotherapy as excuses. In patients with burns of limited extent there is no danger of producing shock and yet early grafting was not tried. Moreover, for many years it has been a common practice, in patients with extensive as well as circumscribed burns, to administer a general anesthetic when scrubbing the wounds before spraying tannic acid. It cannot have been the lack of a nontoxic chemotherapeutic agent because, as pointed out in this paper, penicillin is not even given a chance to play a rôle in the immediate closure of cir-

‡ This statement does not apply to Dr. Donald B. Wells who in 1929 published an article entitled "The Treatment of Electric Burns by Immediate Resection and Skin Graft" in which he described this treatment of three cases.<sup>12</sup> Dr. Wells' treatment resulted from what was learned in the war of 1914-18. He states, "The complete resection of gunshot wounds, more usually spoken of as débridement, and their immediate closure by primary suture or their delayed closure after a few days of chemical sterilization, was a technic developed and perfected during the World War. The application of this principle of complete resection and immediate closure by suture or skin graft to third degree electrical burns has not been reported in the literature, nor has it apparently ever been successfully applied so far as we have been able to learn after diligent inquiry among surgeons who must come into frequent contact with the results of electrical traumata."

## FULL-THICKNESS BURN WOUNDS

cumscribed wounds. Immediate excision and closure precludes infection. It is only in the extensively burned patient, some of whose wounds must await their turn for closure, that a chemotherapeutic agent is needed.

The only explanations at hand for the failure of the surgeon to appreciate the potentialities of early surgical closure of the full-thickness burn wound are his fear of the loss of blood during the excision and the deep rooted fallacy that an unattached graft would survive only on a bed of granulation tissue. The plastic surgeon, who has for years placed free grafts successfully upon the freshly exposed surfaces left after excision of scars, will not be surprised to learn that the base left after excision of burn skin is just as good for the successful take of a graft.

A loss of blood in excising the burn wound is admitted. The volume lost increases with the age and extent of the wound but is never so large that it cannot be replaced. Hemorrhage, therefore, does not exclude surgical excision as a method of getting rid of burn slough. Doctors Connor and Harvey's chemical method of slough separation obviates the blood loss of excision but exchanges for it the loss of time, precious in preventing infection, and an inflammatory base upon which to lay grafts.

### SUMMARY

Full-thickness burn wounds of the skin have always presented a challenge to the surgeon. Invariably infected, the patient has languished interminably in the hospital before successful closure has been achieved and, if the wounds were extensive, the patient has suffered from severe malnutrition.

If the challenge is met by prompt surgical excision of the dead tissue and immediate closure of the wound by grafting, infection is precluded, scar tissue with disfigurement and disability are minimized, the period of hospitalization is curtailed, manpower is economized and the outlook of the patient heartened.

The expeditious treatment of 52 full-thickness burn wounds in 38 patients by surgical excision and grafting at the Massachusetts General Hospital is recounted. Circumscribed burns of full-thickness have been excised and closed by grafting within a few hours after injury; the healing is most gratifying. In the wounds where a delay of days between injury and excision was introduced, infection insinuated itself in spite of the administration of systemic chemotherapy and delayed closure was resorted to in half the cases. The results have been surprisingly good. In the patients with extensive full-thickness wounds, homeostasis has been effected and maintained so that areas have been excised and grafted within the first few days. The care of the other areas has had to be postponed because of the precariousness of homeostasis and lack of sufficient donor skin for the grafting. The longer the delay in closure, the greater has been the infection, the less successful the take of the grafts, and the uglier and more disabling the scarring.

It is hard to convince any but the plastic surgeon, with his experience in excising old scars, that the best base upon which to place a graft is the one freshly exposed, even if edematous, after excision of burn slough.

The problem of the recognition of full-thickness destruction resolves itself with experience in practice.

Chemotherapy is a valuable adjunct in holding invasive infection in abeyance in those cases in which the excision and grafting must be delayed and in which the organisms are amenable. Its services are probably superfluous in those patients whose wounds are excised and grafted within the first hours after injury.

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## ESOPHAGEAL ATRESIA AND TRACHEO-ESOPHAGEAL FISTULA

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ESOPHAGEAL ATRESIA and tracheo-esophageal fistula received comparatively little recognition or interest from clinicians until the last decade, or so, in spite of the fact that the condition had been described by Durston,<sup>1</sup> in 1670, by Gibson,<sup>2</sup> in 1703, and by Martin,<sup>3</sup> in 1821. It is now realized that the anomaly is quite common. Sir G. Gray Turner<sup>4</sup> has recently estimated that the malformation occurs about as frequently as hare lip and cleft palate. It is undoubtedly true that many infants still die of esophageal atresia without its having been diagnosed.

### EMBRYOLOGY

It should be recalled that the esophagus and trachea in early fetal life are one tube. Between the fourth and twelfth week of fetal life this tube becomes divided into two by an ingrowth of mesoderm. During this same period the lumen of the esophagus becomes obliterated by the rapid proliferation and concrescence of its epithelial lining. Later, this solid cord becomes vacuolated, the vacuoles coalesce, and the lumen is reestablished in the same manner as in the intestine. An arrest in development, or failure of the mesoderm completely to separate the trachea from the esophagus, results in the tracheo-esophageal fistula, while failure of the vacuoles to coalesce results in the atresia of the esophagus.

### PATHOLOGY

There is a wide variation in the pathologic findings of these anomalies; in fact, it may be said that no two cases are exactly alike. However, they may be roughly divided into five types, as shown in the diagram (Fig. 1) previously published by Ladd,<sup>5</sup> and described as follows:

"In Type I, the upper portion of the esophagus ends in a blind pouch in the region of the body of the first or second dorsal vertebra, and the lower segment of the esophagus begins again in a blind pouch at the level of the fourth or fifth dorsal vertebra. In Type II, the upper segment of the esophagus ends in a fistulous tract entering the trachea just above its bifurcation, whereas the lower segment is much the same as in Type I. In Type III, the upper segment ends blindly as in Type I, whereas the lower segment is connected to the trachea just above its bifurcation by a fistulous tract. This type and Type

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IV are by far the most common in the reports of the literature as well as in our own experience. Type IV is similar to Type III except that the fistulous tract of the lower segment enters the trachea at its carina instead of just above its bifurcation. In Type V, both the upper and lower segments communicate with the trachea, as shown in the diagram."

#### CLINICAL FINDINGS

If a newborn infant becomes cyanotic and shows an excess of saliva or frothy mucus in the mouth, the diagnosis of esophageal atresia should be considered. If subsequently the infant vomits all fluid offered, almost immediately

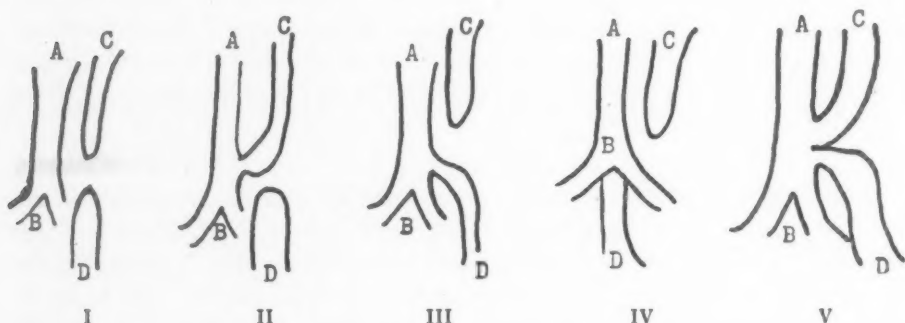


FIG 1.—Diagram showing the arrangement of the trachea and esophagus in the various types of esophageal atresia and tracheo-esophageal fistula.

The letters refer to the following structures: A—trachea; B—bifurcation of trachea; C—upper segment of esophagus; and D—lower segment of esophagus. (From New England Journal of Medicine, 230: 625-637, May 25, 1944.)

after it is given, the diagnosis should be strongly suspected and steps taken to confirm or disprove the suspicion. First, a No. 8-F. or 10-F. soft rubber catheter should be introduced into the esophagus, preferably under the fluoroscope, and if this meets obstruction 10 or 12 cm. from the lips, the diagnosis is confirmed.

#### ROENTGENOLOGIC EXAMINATION

The diagnosis should now be refined to differentiate between the types of the malformation. This may be done with the help of the roentgen ray. With the soft rubber catheter at the point of obstruction, not more than 0.5 cc. of lipiodol is inserted and watched under the fluoroscope, to determine whether there is any connection between the upper segment of the esophagus and the trachea. If a large amount of lipiodol is introduced into an esophagus that ends blindly, it will be regurgitated and aspirated into the trachea and lungs, and confuse the picture. Of course, this same thing would happen if barium were given, which makes its use contraindicated.

Subsequent to the fluoroscopic examination, a roentgenogram should be

## ATRESIA AND FISTULA OF ESOPHAGUS

taken of the chest and abdomen. The chest film will demonstrate the level of the blind end of the upper segment of the esophagus, which is an important factor in determining the plan of operation. It will also supplement the physical examination in estimating the amount of atelectasis or pneumonia, which is usually present in these patients. The examination of the abdomen roentgenologically will show the presence or absence of air in the stomach and intestines.

If the patient has a Type I or II malformation, there obviously will be no air in the stomach or intestines (Fig. 2).

Type II may be recognized by the lipiodol entering the trachea from the esophagus, and showing no air in the stomach.

Types III and IV will show air in the stomach and intestines and no lipiodol entering the trachea from the esophagus (Fig. 3).

Type V, of course, will show air in the stomach and intestines but will also show lipiodol entering the trachea from the esophagus.

Roentgenologic examination of the patient will help the surgeon to determine the preferable plan of treatment, but it should be remembered that associated anomalies may be present and should be sought for before the operation is begun.

The associated anomalies, though frequent, are only rarely of importance in the life or health of the child. Table I represents all the anomalies that have been noted in 114 cases. Although these add up to 91 malformations, in some instances more than one anomaly occurred in one patient, and many were not of a serious nature.

In Table II are classified the number of serious malformations which were observed in the 82 patients who have been admitted to The Children's Hospital since 1939 with esophageal atresia. It is estimated that 18 of these malformations either made it necessary to modify the treatment, or caused the death of the baby.

### PREOPERATIVE PREPARATION

The preoperative preparation of these patients is important. They almost always have respiratory difficulties (pneumonia, or atelectasis) due to aspiration of saliva and mucus. The infant should be placed in an oxygen tent for the administration of oxygen in high concentration. Then a small soft rubber

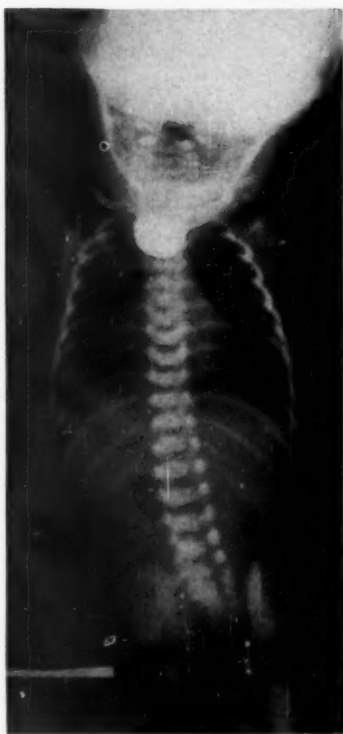


FIG. 2.—Roentgenogram.

catheter is introduced into the pharynx and attached to constant suction. By this means, and keeping the infant in a slight Trendelenberg position, the air passage can be kept fairly clear and respiration made much easier. A small transfusion and parenteral fluids should be given as indicated, care being taken not to overtax the circulation and cause pulmonary edema. Such preoperative preparation will often improve the patient's condition sufficiently to make an operation successful which otherwise would certainly end in disaster.

TABLE I

## ANOMALIES ASSOCIATED WITH ATRESIA OF THE ESOPHAGUS

Type	No. of Cases
Atresia or stenosis of the small intestine.....	7
Meckel's diverticulum.....	8
Malrotation.....	4
Imperforate anus.....	11
Fistula of the rectum.....	4
Anomalies of the heart and aorta.....	20
Congenital anomalies of the urinary system.....	13
Miscellaneous.....	24

TABLE II

## SERIOUS ANOMALIES IN THE LAST EIGHTY-TWO CASES

Type	No. of Cases
Atresia or stenosis of intestine.....	5
Imperforate anus.....	5
Congenital heart.....	13
Anomalies of the urinary tract.....	2

## OPERATIVE APPROACH

All attempts to remedy esophageal atresia with tracheo-esophageal fistula, without direct ligation of the fistula, have failed.

The direct approach to the site of the atresia and fistula may be made through the left back or the right back, and may be transpleural or retropleural. In 1941, Mr. R. H. Franklin<sup>4</sup> performed a primary anastomosis through a transpleural approach, but the patient unfortunately died 17 hours later. At the Children's Hospital this transpleural approach has been used on seven patients. Doctor Swenson used this approach to tie off the tracheal fistula (See Case Report No. 304556) in one patient with other malformations, and the baby survived. Doctor Gross used it on five patients with one successful primary anastomosis and four fatalities, and Doctor Ladd used it once without success.

✓ This transpleural approach has some theoretic advantages. With the long intercostal incision or a resection of a long segment of the fifth rib an excellent

exposure may be obtained quickly with slight injury to the thoracic cage. However, while this approach is made more quickly, the closure is time-consuming and the total operating time is not diminished. Furthermore, if a leak takes place at the anastomosis the chest fills with saliva and gastric contents, and in all cases in which this complication has occurred the outcome has been fatal. If the retropleural approach is used and a similar complication arises, a fistula to the back is established, and in several such instances the baby has survived. We, therefore, prefer the retropleural approach through the right back.

Although Dr. Cameron Haight<sup>6</sup> has reported successful results using the route through the left back, in the two instances in which we have used that approach the result has been fatal. All but two of our favorable results, and the majority of those found in the literature, have been accomplished by retropleural operations through the right back.

#### TECHNIC OF OPERATION

Cyclopropane has been the anesthesia of choice in our experience. If local anesthesia is used it should be supplemented by a closed system with oxygen to combat collapse of the lung in case the pleura is inadvertently opened. An intravenous needle is inserted into an ankle vein for the administration of blood or fluid during the operation. The patient is placed on the operating table left side down, with a folded towel to give the spine a slight curve with the convexity upward toward the right side. The right arm is abducted to displace the scapula laterally.

An incision is now started at the level of the second rib between the internal border of the scapula and the spine. This incision is carried downward to the level of the sixth rib where it swings laterally for two or three centimeters. After the incision has been carried through the trapezius and rhomboid muscles the scapula is displaced laterally and the ribs exposed. In our earlier cases a rather long section of the fourth rib was resected and short sections of the third and fifth were resected or only cut. More recently, however, a better exposure has been obtained by resecting one to two centimeters of the second to the fifth ribs, inclusive, or the third to the sixth, according to the level of the upper blind pouch of the esophagus. This approach more closely resembles that recommended by Haight.<sup>6</sup>

After the small sections of rib have been resected, the intercostal muscles, with the intercostal vessels and nerves, are tied and cut. The pleura is then carefully freed from the posterior thoracic wall, toward the bodies of the vertebrae. The first anatomic landmark is the sympathetic chain, with its

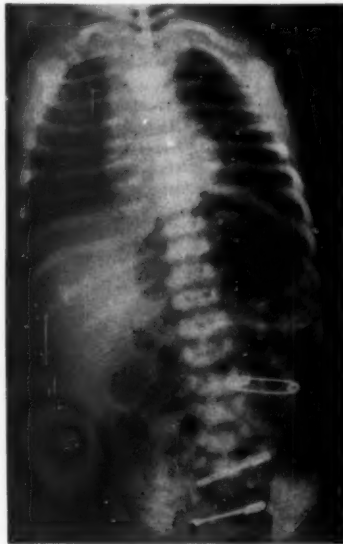


FIG. 3.—Roentgenogram.

ganglia. The azygos vein then comes into view, and this is isolated until its terminal trunk is exposed as it crosses the mediastinum. This is then tied and cut. When the two ends are pushed aside, the vagus nerve is readily located and this gives a direct lead to the segments of the esophagus.

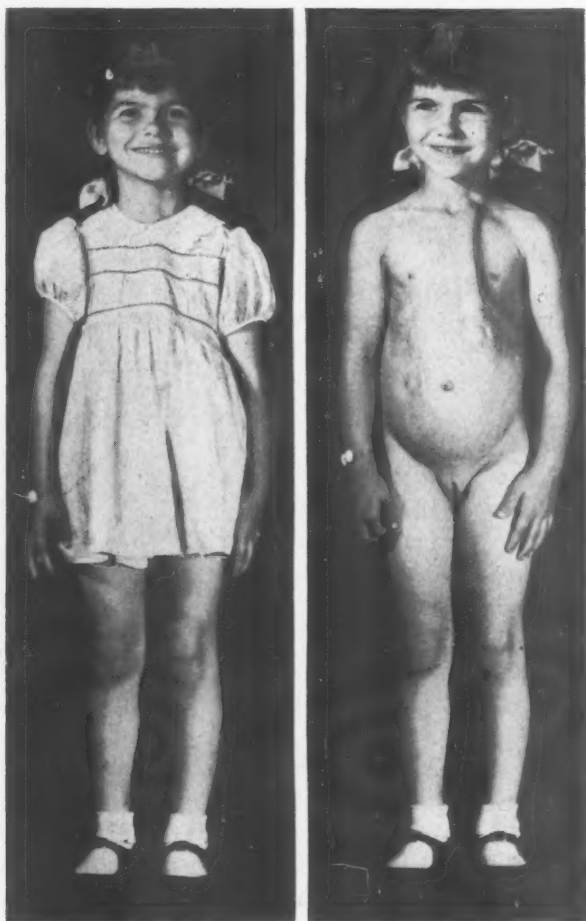


FIG. 4.—This is Doctor Ladd's oldest patient, now six and one-half years of age. She takes a normal diet by mouth, attends school, and engages in all activities of a normal child.

It is at this point that judgment and experience are of value in determining whether to attempt a primary anastomosis, or to perform the simpler operation of tying and cutting the tracheo-esophageal fistula. This decision depends on two factors, the condition of the patient, and the distance between the two ends of the esophagus. If the space between the two segments of the esophagus is much over two centimeters, the possibility of being able to do an anastomosis without tension is not good.

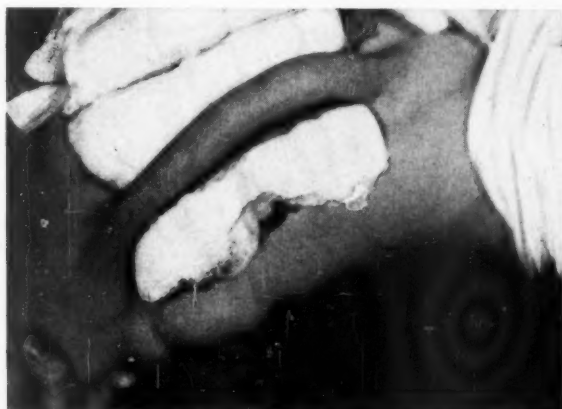


## ATRESIA AND FISTULA OF ESOPHAGUS

### PRIMARY ANASTOMOSIS

When the conditions indicate the desirability of an end-to-end anastomosis, the following steps are taken: First, the upper, blind end is freed well up above the first rib, so that it can be brought to the lower end without tension. Next,

A



B



C

FIG. 5.—A. A rope graft has been made on the right lateral aspect of the chest and right axilla.

B. Three weeks later the lower end of the rope was swung and sutured to a point just above the esophagostomy.

C. The dermic tube has been turned in and covered with the rope graft. The patient is now ready to have a jejunal segment anastomosed to the skin tube.

the lower segment is isolated and is cut away from the trachea almost in the tracheal wall, in order to give it maximum length. As the esophagus is separated from the trachea, the opening into the trachea is closed by a running

suture of fine silk, and this row of sutures is, in turn, covered by a second layer of running sutures of the same material. The final step is the suturing together of the two ends.

In our recent cases, the musculature is first approximated on the back of the esophagus by interrupted fine silk stitches, including muscle layer only.

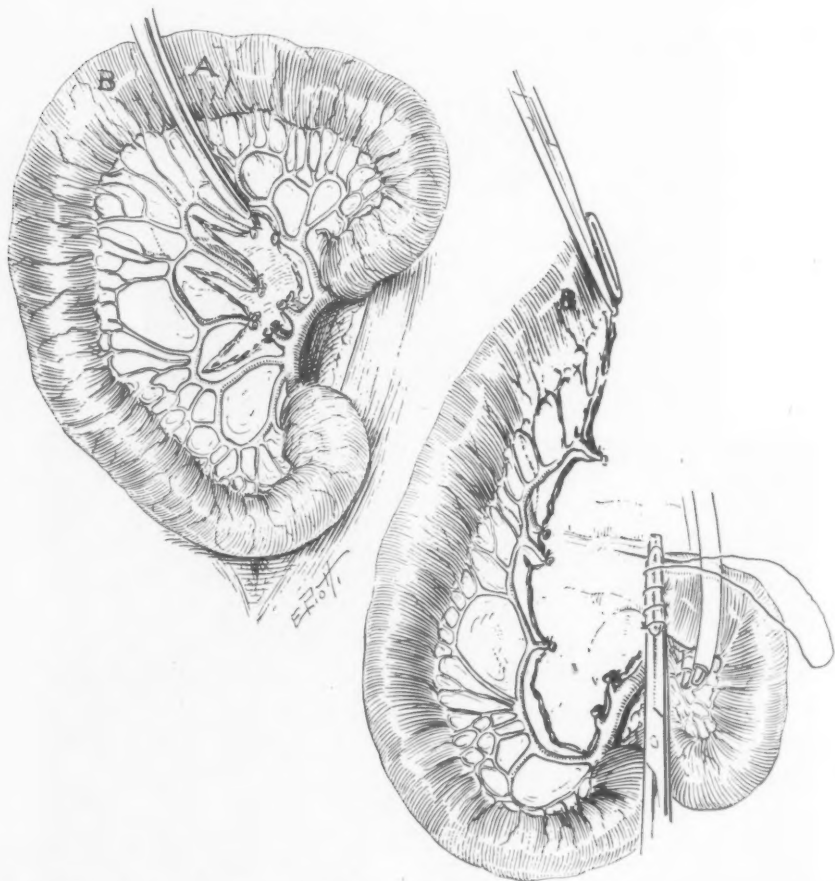


FIG. 6.—Note in drawing two intestinal vessels have been cut and the mesentery has been divided up to the first arcade, thus freeing a segment of jejunum.

Approximation stitches are then placed in the mucous membrane, likewise on the back part of the esophagus. The interrupted sutures are then applied to the front part of the esophagus to complete the closure of the mucous membrane, and following this a second layer of interrupted stitches is applied to the musculature only.

After the anastomosis has been completed, about 10 cc. of penicillin, containing 5,000 units per cc., is placed in the retropleural space, and a small rubber dam drain is inserted to the mediastinum. The opening in the chest

wall is closed to the drain by suturing together, first the intercostal bundles, then the rhomboids, and then the trapezius. Finally, the skin is closed over this with an interrupted or a running silk suture.

In our first successful cases of direct anastomosis, the catheter which was in the upper blind pouch during the operation was introduced into the stomach through the anastomosis and left in place for a week or ten days. More recently, the catheter, which it is desirable to have in the upper segment of the esophagus during the operation, has been removed at the end of the operation. We feel that this diminishes the chance of respiratory infection and of infection of the anastomosis. Postoperatively, the patient's fluid balance is maintained by transfusion of blood or plasma, and by intravenous fluids of saline or glucose. During this period, also, the patient is kept in an oxygen tent. In from 24 to 48 hours, according to the condition of the patient, gastrostomy is performed for feeding. In case there is no leakage from the anastomosis, feedings by mouth are begun at the end of the 10th to 12th day. In case of leakage, feeding by mouth is postponed until the fistula has closed.

#### MULTIPLE-STAGE

In patients in whom the ends are too widely separated to warrant a primary anastomosis, a multiple-stage procedure is adopted. At the first operation the site of the atresia is approached exactly as described for the operation of primary anastomosis. The lower segment of the esophagus is cut away from the trachea at the site of the fistula, both ends tied, and an over-and-over stitch placed to insure against leakage. This having been done, the chest wall is closed as before.

During the next few days the patient is kept in slight Trendelenberg position and constant suction applied to the upper segment of the esophagus to prevent aspiration of saliva and mucus. In this interim the baby's fluid balance is maintained by intravenous administration of blood or plasma, and saline or glucose solutions. At the end of two or three days, under local or cyclopropane anesthesia, a gastrostomy is performed through a high left rectus incision. This enables the infant to be fed and obviates the necessity of continuing parenteral fluids.

The third stage of the operation is performed one or two days after the gastrostomy, and consists of bringing the upper segment of the esophagus out in the neck. The procedure is to make a small inverted V-shaped incision 1.5 cm. above the clavicle, starting at the midline and carrying it laterally to the left for a distance of 3.5 cm. The trachea is displaced from the operative field by extending and rotating the head to the right. The fibrous band extending downward from the lower end of the upper segment of the esophagus into the mediastinum must be cut before the blind end can be delivered. The esophageal pouch is opened and the cut edges approximated to the skin with interrupted silk sutures. Now the patient can swallow saliva and is no longer in danger of aspiration pneumonia.

After these procedures have been completed, an indefinite period may elapse before the anterior thoracic esophagus is constructed.

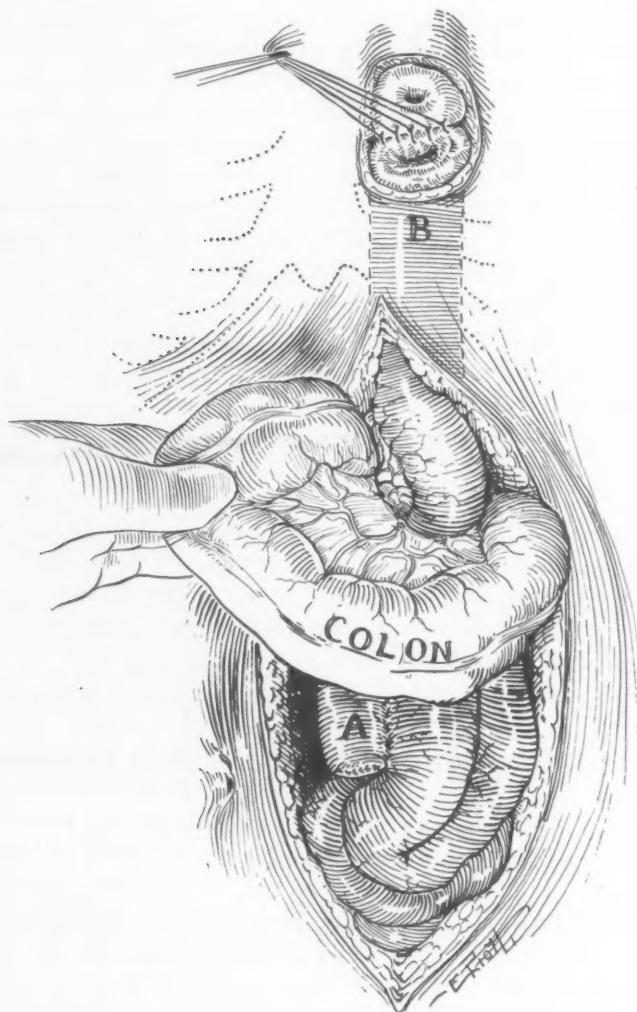


FIG. 7.—The freed segment of jejunum has been tunneled under the skin of the lower chest wall. The jejunum is being anastomosed to the skin tube. A side-to-side anastomosis has been made between the proximal and distal segments of the jejunum.

#### ANTERIOR THORACIC ESOPHAGUS

Surgeons have employed many methods of constructing an anterior thoracic esophagus. In our oldest patient, now over six and one-half years old, the stomach and esophagus were connected by an epithelial-lined tube made over the left chest wall and covered by a tube graft taken from the right axilla. The

## ATRESIA AND FISTULA OF ESOPHAGUS

child upon whom this series of operations were performed is a happy and healthy girl, who takes a varied diet by mouth, goes to school, and leads a nearly normal life. Occasional dilatations of the anastomosis between the skin tube and the stomach are necessary. The details of this method were described in a previous communication<sup>5</sup> (Fig. 4).



FIG. 8



FIG. 9

FIG. 8.—A photograph of patient No. 267162, now four years of age. It is more than a year since completion of the anterior thoracic esophagus. A regular diet is taken without difficulty.

FIG. 9.—Note the catheter in the upper blind pouch, markedly dilated heart, and tremendous distention of stomach and duodenum, with no air in the intestinal tract below the duodenum.

Although anastomosis of the skin tube directly to the stomach has been successful in one case, there are obvious disadvantages. These may be obviated by uniting the skin tube to a jejunal segment. The steps in this operation are as follows: First, a tube or rope graft is elevated in the right axilla and the raw surface underlying this covered by a Thiersch graft. At the end of three weeks the lower end of this tube graft is freed, swung up to the left side of neck and implanted just above the esophagostomy. After approximately another three weeks, when it has acquired adequate circulation, the new esophagus is ready to be constructed. This is done by turning down a V-shaped flap from above the esophagostomy and under the attachment of the tube graft. Next, two parallel incisions are carried downward on the left chest wall. These



release the skin flaps which are turned toward each other and sutured together and to the V-shaped flap of skin which has been turned downward from the neck. Thus, is formed an epithelial-lined skin tube leaving a raw surface outside. The axillary end of the tube graft is now detached, the tube is unfolded and used to cover the raw surface left by making the skin-lined esophagus (Fig. 5).

After these wounds are completely healed, and any induration which may be present has subsided, the next step is to unite a segment of jejunum to this skin tube. This is done through a left rectus muscle-splitting incision extending downward from the costal margin. The proximal loop of jejunum is iden-

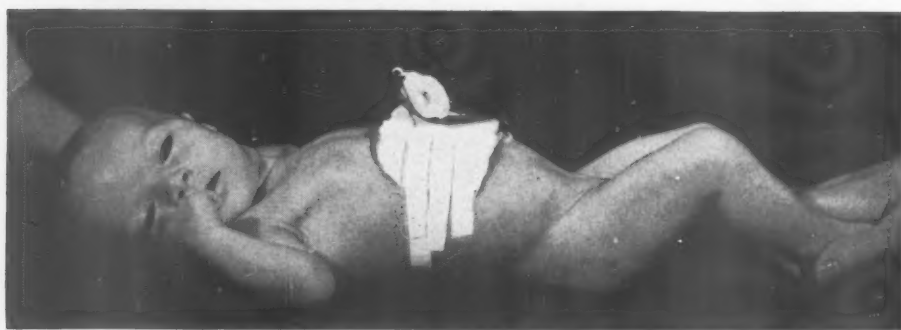


FIG. 10.—Case No. 306150: Fifteen days postoperatively. At this time all feedings were well taken by mouth.

tified and one of the first intestinal vessels is isolated, ligated, and divided as close to the mesenteric artery as possible. The jejunum is divided about six inches from the ligament of Treitz and the mesentery divided from this point on the bowel to the divided mesenteric vessel. Closure of the proximal end of the jejunum is now carried out. The distal segment is free and is usually long enough to extend 6 or 8 cm. on the chest wall above the costal margin. Should the distal segment fail to reach such a position, the mesentery can be freed further by division of a second intestinal artery and vein close to the mesenteric vessels. The avascular portion of the mesentery up to the first arcade is divided, giving sufficient length to the distal segment of jejunum (Fig. 6). The skin of the chest is tunneled under from the cephalic end of the incision to a point under the opening of the skin tube.

An incision is made across the bottom of the skin tube and the overlying skin is separated from the dermic tube. Anastomosis of the skin tube is accomplished by a posterior row of interrupted fine chromic catgut sutures through the serosa and muscular coats of the jejunum to the subcutaneous tissue of the skin tube. A row of chromic catgut sutures is placed through all layers of the jejunum and the skin of the tube. The anastomosis is completed anteriorly by a row of interrupted chromic catgut sutures through the serosa and muscular coats of the jejunum and the subcutaneous tissue (Fig. 7).

## ATRESIA AND FISTULA OF ESOPHAGUS

This procedure is a combination of parts of technic previously published by Wullstein,<sup>7</sup> Davis,<sup>8</sup> and Ladd.<sup>5</sup>

Providing there is no evidence of inflammation at the site of the dermo-jejunal anastomosis, the patient is given water by mouth on about the tenth postoperative day. In two out of five cases fistulae developed at this point, but both closed spontaneously.



FIG. 11.—This child is now eight months postoperative, and doing well. She is a perfectly normal child, taking a regular baby diet. Dilatations of the esophagus have not been necessary.

The ease with which these patients can swallow liquids and solids is gratifying. Only occasionally is it necessary to promote the emptying of the skin tube by manual pressure.

### SUMMARY OF TWO UNUSUAL AND FOUR TYPICAL CASES

**Case No. 267162.**—Surgeon W. E. L.: This patient was first admitted October 19, 1942, and a diagnosis of esophageal atresia and tracheo-esophageal fistula was made. Exploration of the mediastinum was carried out with ligation of the fistula. Two days following this, gastrostomy and marsupialization of the esophagus were performed. He

did well until the sixteenth postoperative day, when he coughed up some material resembling formula. Reexploration of the mediastinum demonstrated the reestablishment of the tracheo-esophageal fistula. This was ligated and divided.

At 15 months of age an anterior dermo-esophagoplasty was performed in three stages. At the age of two years and seven months a jejunal segment was brought up and anastomosed to the skin tube. On the tenth postoperative day liquids were taken well by mouth and the patient was soon able to take solids. It is only occasionally necessary to manually decompress the skin tube. At the age of four years he continues to do well but has had one dilatation of the skin-tube-jejunal anastomosis, which was probably unnecessary (Fig. 8).

**Case No. 286815.**—Surgeon W. E. L.: This infant had esophageal atresia of Type III and an associated duodenal atresia and congenital heart disease. At the first operation



FIG. 12.—This is patient No. 298835 at six months of age, after primary anastomosis of the esophagus. He has no difficulty in taking a normal baby diet. Dilatations of the esophagus have not been necessary.

the tracheo-esophageal fistula was excised and a duodenojejunosomy and gastrostomy performed. A few days later the upper blind segment of the esophagus was marsupialized in the neck. The patient is now two years old, in excellent health, and awaiting the construction of an anterior thoracic esophagus.

**Case No. 306150.**—Surgeon W. E. L.: This four-day-old baby was admitted with a diagnosis of atresia of the esophagus with tracheo-esophageal fistula. After 24 hours of preparation the mediastinum was explored through a right-sided retropleural approach. A Type III fistula was found, which was ligated and divided. The upper esophageal pouch was about 0.5 cm. above the fistula and when freed could be brought down to the lower segment with little if any tension.

A primary anastomosis was made and postoperatively the baby did well. On the first postoperative day a gastrostomy was carried out under local anesthesia. Feedings by gastrostomy were well tolerated, and on the tenth postoperative day feeding by mouth in small amounts was started. By the 15th day after operation all feedings were taken orally, and the patient had gained in weight by the 16th day. The gastrostomy tube was removed. The baby was discharged on the 18th postoperative day (Fig. 10).

**Case No. 297981.**—Surgeon O. S.: This four-day-old baby girl was unable to take and retain even small amounts of fluid. Soon after the diagnosis of atresia of the esophagus with tracheo-esophageal fistula was made, and verified roentgenologically, the mediastinum was explored and a Type III tracheo-esophageal fistula was found. The upper esophageal

## ATRESIA AND FISTULA OF ESOPHAGUS

pouch was on the same level with the tracheo-esophageal fistula, so that a primary anastomosis could be made without tension on the suture line.

Postoperatively, the baby did well, in spite of evidence of congenital heart disease. Gastrostomy was performed under local anesthesia on the second postoperative day. Feedings by gastrostomy were well tolerated, and on the 10th day feedings were gradually started by mouth. By the 12th day all feedings were taken by mouth and the child was discharged home on the 19th postoperative day, where she has continued to do well, gain weight, and take her feedings without difficulty (Fig. 11).

**Case No. 298835.**—Surgeon O. S.: This four-pound, four-ounce baby boy was admitted to the Children's Hospital at two days of age, with the diagnosis of esophageal atresia and tracheo-esophageal fistula. A mediastinal exploration was performed through a right retropleural approach. A Type III fistula was found and divided. As the two esophageal segments were only one centimeter apart, a primary anastomosis was made.

Postoperatively, the child did well, and on the second day gastrostomy was performed under local anesthesia. He developed bilateral bronchopneumonia and was severely ill for several days. On the 10th day feedings in small amounts were given by mouth. He was discharged on the 30th postoperative day, and has continued to do well at home. He is now eight months old. (Fig. 12).

**Case No. 304550.**—Surgeon O. S.: This two-day-old baby was admitted with a diagnosis of esophageal atresia and tracheo-esophageal fistula. The abdomen was markedly distended and a roentgenogram demonstrated atresia of the terminal ileum. Bile-stained material was coughed up by the baby.

Through a transthoracic approach the tracheo-esophageal fistula was ligated and divided. Although the upper esophageal segment was within 1.5 cm. of the fistula a primary anastomosis was not done, as the time consumed would have been prohibitive. A long abdominal incision was made, and a malrotation and atresia of the ileum with a minute cecum and colon were found. The terminal ileum ended in a bulbous sac about five centimeters in diameter. The malrotation was corrected and the terminal bulbous ileum was resected with a Mikulicz spur between the terminal ileum and cecum. A gastrostomy was also made. Nineteen days later the ileostomy was closed. Two weeks later a primary anastomosis of the esophagus was made through a retropleural approach. Ten days later feedings were well taken by mouth. The patient continued to do well, and was discharged taking all feedings by mouth and gaining weight (Fig. 13).



FIG. 13.—Roentgenogram of patient No. 304556. This upright film shows consolidation consistent with pneumonia or atelectasis, and evidence of atresia of the lower ileum.

### RESULTS

Since January, 1939, 82 cases of esophageal atresia have been seen at the Children's Hospital. Of this number, 76 have been operated upon by Ladd.

Gross, and Swenson. Four of the remaining six cases were moribund at the time of admission to the hospital, dying within a few hours. Two with multiple associated anomalies, operated upon by other members of the staff, will not be included in the consideration of the results. Table III shows the results obtained in this series of 76 cases.

TABLE III

SUMMARY OF CASES OF ATRESIA OF THE ESOPHAGUS  
WITH TRACHEOESOPHAGEAL FISTULA  
AT  
THE CHILDREN'S HOSPITAL  
JANUARY 1940-JULY 1946

SURGEON	NUMBER OF CASES MULTIPLE STAGE OPERATION		NUMBER OF CASES PRIMARY ANASTOMOSIS		TOTAL NUMBER OPERATIONS		MORTALITY	REMARKS
	LIVING	DEAD	LIVING	DEAD	LIVING	DEAD		
LADD	19	21	4	7	19	28	59%	ONE DEATH RESULTED FROM PERITONITIS AFTER THE COMPLETION OF AN UNSATISFACTORY ANTERIOR THORACIC ESOPHAGUS. ONE DEATH WAS OF UNKNOWN CAUSE FOLLOWING IMMUNIZATION FOR MEASLES, ALSO AFTER THE COMPLETION OF ANTERIOR THORACIC ESOPHAGUS.
GROSS	0	3	4	10	4	14	75%	THREE DEATHS OCCURRED IN PRIMARY ANASTOMOSIS CASES BY THE TRANS-PLEURAL ROUTE. ONE HAD OTHER SERIOUS MALFORMATIONS. ONE PATIENT WHO HAD DUODENAL STENOSIS HAD AN ABDOMINAL OPERATION ONLY DIED AND IS NOT INCLUDED IN THE TOTAL CASES.
SWENSON	1	3	6	1	7	4	36%	ONE SURVIVING PATIENT HAD AN ILEAL ATRESIA AND FIRST THE TRACHEAL FISTULA WAS TIED OFF BY THE TRANS-PLEURAL ROUTE AND LATER A PRIMARY ANASTOMOSIS BY THE EXTRAPLEURAL APPROACH WAS CARRIED OUT.
TOTAL	16	27	14	18	30	45	60%	

## COMMENTS

The time has obviously passed when obstetrician, or pediatrician, should advise parents of infants with esophageal atresia that nothing can be done for them. The time has now come when alertness in making an early diagnosis of this disease may lead to successful treatment. Obstetricians and pediatricians have the opportunity of seeing these patients first, and mortality in the future will depend to a large extent on their quick recognition of the condition and prompt transfer of the patient to a hospital equipped to care for the child properly.

✓ The operation of primary anastomosis, done *via* an approach through the right back, is beyond question the operation of choice when feasible. Our recent results strongly suggest that the suturing should be done with two rows



## ATRESIA AND FISTULA OF ESOPHAGUS

of interrupted fine silk sutures, one to the mucous membrane and one to the musculature. This belief agrees with the experimental work done by Swenson and Magruder<sup>9</sup> in suturing the esophagus in animals. To avoid strain on the suture line, it may be supplemented by the whip-stitch previously described by Ladd<sup>5</sup> or perhaps better by fixing the upper segment of the esophagus to the fascia of the chest wall (as practiced by Swenson). The use of penicillin locally in the mediastinum, followed by the administration of penicillin and sulfadiazine, as well as elimination of the catheter through the anastomosis, have probably been factors in reducing the mortality due to infection. Our last seven cases of primary anastomosis record no deaths.\*

The multiple-stage operation should be employed only in those patients in whom the two ends of the esophageal segments are so far apart that they can not be sewed together without tension, or in those patients who have serious associated anomalies, or who for some other reason are particularly bad risks. The multiple-stage procedure requires prolonged hospitalization and much patience on the part of the surgeon. However, as a method of the immediate avoidance of a fatality, it has its place. We have now five cases in which the anterior thoracic esophagus has been completed. It is functioning satisfactorily in four of them, and we feel should function well in the fifth but for the child's being mentally deficient. We have 11 other patients awaiting the construction of an anterior thoracic esophagus.

The senior writer feels that in the early part of the series he made mistakes in both directions in the selection of plan of operative treatment. That is, he has attempted primary anastomosis in some cases where the multiple-stage procedure was indicated in view of present knowledge, and *vice versa*. In the latter part of the series, both writers have profited by early mistakes. As the result of our experience, the mortality from esophageal atresia should be still



FIG. 14.—This three-year-old child is the oldest living patient of Doctor Ladd, with a primary anastomosis, in our series. She is a perfectly normal child, taking a regular diet. Dilatations were performed during the first year. They have not been necessary during the past two years.

\* Since submitting this communication for publication, there have been an additional seven cases, with one death.

further reduced. There undoubtedly will continue to be an appreciable mortality due to associated anomalies incompatible with life.

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## PULSION DIVERTICULUM OF THE PHARYNGO-ESOPHAGEAL JUNCTION: TECHNIC OF THE ONE-STAGE OPERATION\*

A PRELIMINARY REPORT

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FOR MANY YEARS there has been a division of opinion among surgeons concerning the technic to be used in the operation for excision of diverticula of the pharyngo-esophageal junction. Early attempts to perform the operation in one stage led to discouragement as a result of the frequent occurrence of deep cervical or mediastinal infection and the development of fistulae. To avoid these complications it seemed logical to divide the operation into two stages: The first, including merely the mobilization of the diverticulum and its implantation in the superior portion of the wound; and the second, involving the actual excision of the sac and the closure of the opening at its neck. The late Dr. Charles Mayo<sup>1, 2</sup> was an early advocate of this method. More recently, Lahey has done much to popularize the two-stage technic.<sup>3</sup>

A review of the technical details of the earlier one-stage methods suggests the reasons for the difficulties which were encountered. Large sizes of ligatures and suture material (often chromic catgut) were frequently used. The diverticulum was usually tied at its neck, cut with the cautery or with a knife moistened with carbolic acid, and its stump inverted with a purse-string suture into the wall of the esophagus. An abscess resulting from the necrosis of this ligatured stump would then form in the wall of the esophagus or hypopharynx. If this broke into the lumen as a result of the cutting through of the ligature, no serious immediate consequence was experienced, although the delayed healing eventuating from this tended to result in a stenosis in some cases. In these, subsequent dilatation was necessary. If the abscess around the necrotic stump broke through the outer wall, the inevitable infection, followed by fistula formation, was often of serious consequence. The development of infection and fistulae was often further forwarded by the use of an inlying stomach tube or by instrumentation with a bougie or an esophagoscope at the time of performing the operation in an attempt to make it easier to find the diverticulum. In some cases also the tendency toward the occurrence of infection was possibly increased by the injudicious use of drains.

Although the two-stage operation has been shown to minimize to a large extent the occurrence of serious infection such as acute postoperative mediastinitis, it has not prevented the occasional development of a fistula. It is subject also to the objection which can be used against all two-stage surgical procedures, that in addition to the increased annoyance to the patient, it prolongs to a very appreciable extent the duration of stay in the hospital. Harrington,<sup>4</sup> in a recent review, in which he states that he has given up the two-stage operation, points out that the duration of hospitalization averages more

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\* From the Surgical Services of the Massachusetts General Hospital.

than two weeks longer with the two-stage procedure than when the one-stage operation is used.

#### TECHNICAL PRINCIPLES

The adoption of certain elementary details of technic and the utilization of the protection against infection which may be provided by chemotherapeutic agents, such as penicillin and sulfadiazine, make it possible to abandon the two-stage operation in favor of a one-stage procedure which can be expected to result in a minimum of complications and which greatly shortens the period of hospitalization during the recovery period.

No organ of the body responds more kindly to careful handling than the esophagus. It is a thin-walled, delicate structure which lacks a serosal covering. Its blood supply is segmental in origin. In handling it, unnecessary trauma must be avoided. Forceps should be delicate and used sparingly. Allis or Babcock clamps should never be applied to its walls. Dissection must be accurate and no more extensive than necessary, in order to avoid damage to the blood vessels. Sutures must be placed with care and tied without tension so as to avoid crushing the tissues. The layers must be approximated accurately. Cut-edges should never be seared with a cautery, crushed with a clamp, or treated with caustic liquids, such as carbolic acid. In short, any suture of the wall of the esophagus, whether in the performance of an anastomosis or the closure of the opening left after excising a diverticulum, must (1) avoid damage to the cut-edge; (2) secure an accurate layer-by-layer approximation of the edges to be united; and (3) insure an adequate blood supply to the sutured edges.

The adoption of these principles of technic is of primary importance. But there can be little doubt that the additional assistance to be obtained by using sulfadiazine and penicillin to increase the resistance to infection is also important to obtain the best results.

The chances of success are further increased by avoiding all extraneous sources of trauma to the newly sutured edges, such as inlying tubes within the lumen of the esophagus and drains placed too close to the suture line. The use of a drain is not necessary if the field is absolutely dry at the conclusion of the operation.

#### PREOPERATIVE PREPARATION

The patient should be in the hospital a few days before the performance of the operation to provide an opportunity for thorough evaluation of his general physical condition. This preliminary period, furthermore, allows the patient to rest and to become adjusted to the hospital routine. During the 48 hours immediately preceding operation five grams of sulfadiazine is given each day and 12,000 units of penicillin are administered intramuscularly every three hours.

#### TECHNIC OF OPERATION

The operation is performed under ether anesthesia, using an intratracheal tube. The left side of the neck is chosen unless the case happens to be one

# PHARYNGO-ESOPHAGEAL DIVERTICULA

where the diverticulum bulges to the right, when the right-sided approach is preferred. An oblique incision is made along the anterior border of the sternocleidomastoid muscle. This incision is deepened through the platysma muscle. The omohyoid muscle is exposed and retracted downwards and medially. The sternomastoid muscle is retracted posteriorly. The left lobe of the thyroid and the overlying sternohyoid muscle are then retracted medially. The inferior thyroid vessels are usually encountered. If they interfere with the exposure,

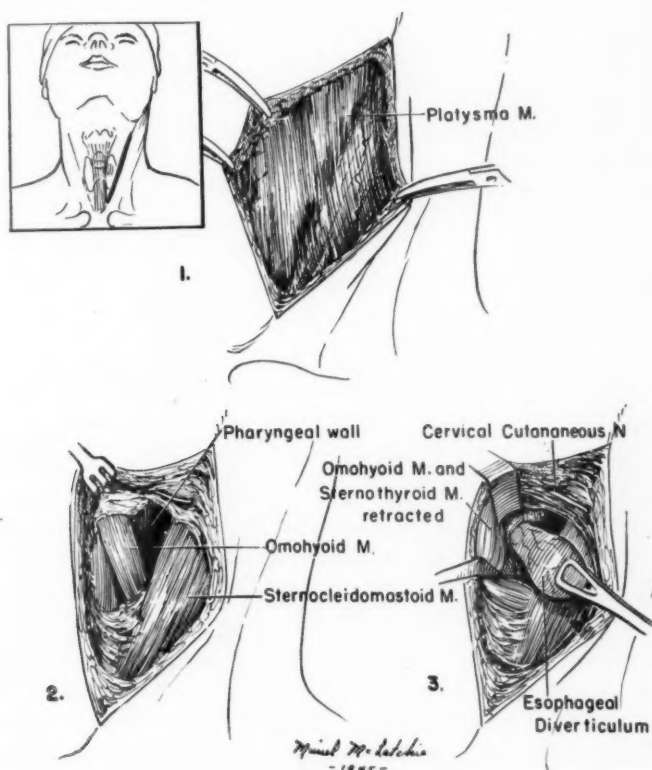


FIG. 1.—Diagram to show the position of the incision (inset) and the stages of dissection. (1) Skin incision retracted exposing the platysma muscle. (2) Cut-edges of skin and platysma muscle retracted exposing the omohyoid muscle, the sternocleidomastoid muscle, and the lateral wall of the pharynx. (3) Diverticulum completely freed and drawn out of the wound in preparation for excision.

they are divided between silk ligatures. The carotid sheath and its contents are retracted laterally. By blunt dissection with the scissors the retropharyngeal space is entered and by enlarging the dissection downwards in this plane the diverticulum can be found with ease. Gentle dissection frees the fundus of the diverticulum which can then be grasped with a forceps and drawn through the wound. The neck of the sac is developed carefully. In doing this



a small artery is usually found extending from the pharyngeal wall onto the posterior surface of the diverticulum. This should be tied and cut.

The removal of the diverticulum is now begun. A serious objection to some of the methods of removal which have been advocated is that the diverticulum

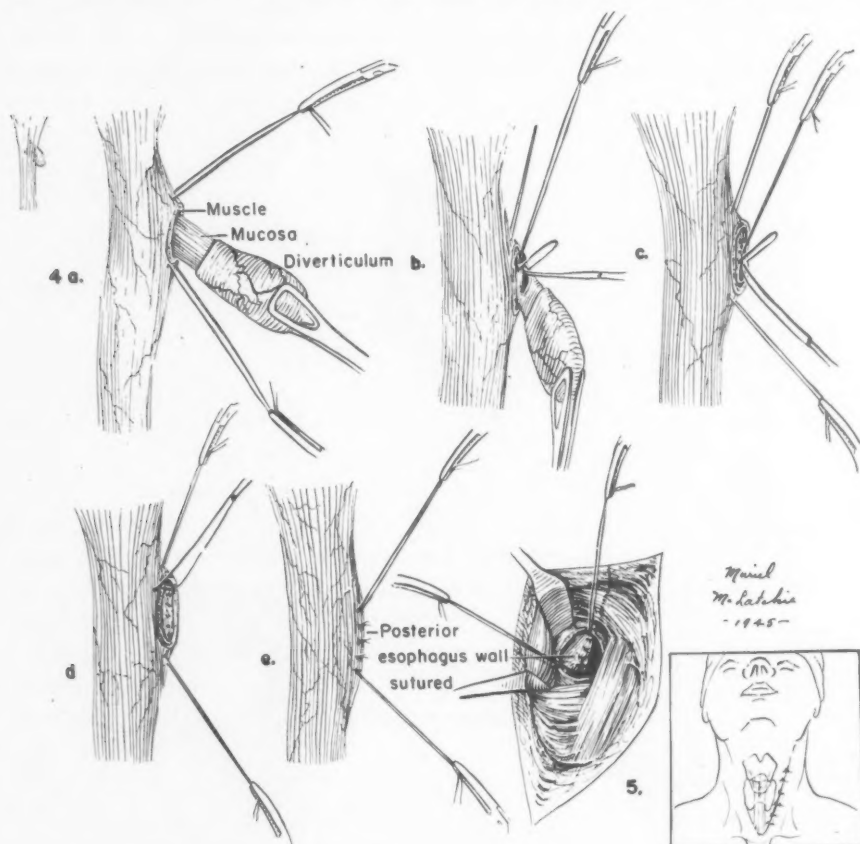


FIG. 2.—Diagram to illustrate the steps of excision of the diverticulum and the closure of the resulting defect. (4a) Incision through the muscular layer completed. Mucosa not yet cut, stay-sutures at upper and lower ends of muscle incision. Note retraction of muscularis. (b) Incision of the mucosa begun. First mucosal suture tied; second suture placed but not yet tied. (c) Diverticulum removed; mucosal suture continued. (d) Closure of mucosal layer completed; first muscle layer suture placed but not tied. (e) Closure of muscle layer completed. (5) *In situ* view of the field of operation before closure of the wound.

Inset: Operation complete. No drain.

was tied at its base and inverted into the wall of the esophagus with a purse-string suture. To avoid this unnecessarily clumsy method, the diverticulum may be cut at its base and the resulting defect closed in two layers with interrupted fine silk sutures. This eliminates the presence of a stump of tissue which inevitably becomes necrotic, and avoids the danger of constricting the esophageal lumen by substituting a neatly closed vertical incision for the

## PHARYNGO-ESOPHAGEAL DIVERTICULA

bunched-up wall at the site of inversion of the tied-off stump. An important detail of technic in this step of the procedure is to cut through the outer layers of the diverticulum an appreciable distance from its base where it joins the pharyngeal wall. This makes allowance for the unavoidable tendency of the muscularis to retract. If this precaution were not observed, the edges might separate so widely that too much tension would be required to approximate them and proper healing might be interfered with. After circumcising the muscular coat of the diverticulum near its base, stay-sutures of fine silk are placed, one at each end through the muscularis (Fig. 2, 4A). The incision of the mucosa is then begun and after cutting it through part way, the first mucosal suture is placed and tied. Using this stitch for traction, the remainder of the mucosa is cut and the approximation of the two mucosal edges is completed using interrupted fine silk sutures placed in such a way that the knots are tied on the lumen side. No effort is made to invert the edges. If the incision through the muscularis has been properly placed, the edges of the muscular layer can now be approximated with fine silk sutures without any tension (Fig. 2). After closure of the muscular layer has been completed, the stay sutures at each end are withdrawn and the esophagus and pharynx are allowed to drop back into place.

The left lobe of the thyroid and the omohyoid and sternocleidomastoid muscles are then allowed to resume their normal position and the wound is closed with a layer of fine silk sutures in the platysma muscle and a second layer in the skin.

### POSTOPERATIVE MANAGEMENT

The patient is allowed to be out of bed on the day after that of the operation. On that day also a few sips of water or normal saline solution are allowed each hour to prevent excessive dryness of the mouth. The necessary amount of fluid containing glucose and saline as indicated is administered by venoclysis. Sulfadiazine is given intravenously, usually 2.5 grams per 24 hours for approximately three days. The administration of penicillin is continued for approximately five days. Liquid food is allowed sparingly on the third day and the amount gradually increased during the next few days. Soft solids are given cautiously by the end of one week and from then on the amount and kind of solid foods are rapidly increased. A normal diet can be taken by the end of two weeks. The patient is usually ready for discharge from the hospital by the tenth postoperative day.

### RESULTS

Although the number of cases is small (five in all), the complete freedom from complications of any sort suggests that this one-stage operation is worthy of further trial. The average stay in the hospital after the performance of the operation has been 11 days. Two illustrative case reports are submitted.

### CASE REPORTS

**Case 1.**—M. G. H. No. 477674: W. G., female, age 75, was admitted to the Baker Memorial Hospital on January 25, 1945. She had first learned that she had a pouch in

her esophagus eight or nine years previously. It appeared to have increased in size until at the time of admission it would fill up enough to interfere with her voice and her swallowing. She could regurgitate food from the pouch. She was otherwise asymptomatic.

Physical examination showed a thin, frail-appearing, very active woman. Examination was entirely negative. There were no palpable masses in the throat and no audible gurgling. Blood pressure 100/65.



FIG. 3.—Case 1: Roentgenogram showing a large pulsion diverticulum of the pharyngo-esophageal junction extending into the superior mediastinum.

Laboratory studies revealed a white blood count of 6800, photo. hemoglobin of 10.7 Gm. The serum protein was 6.4 mg. per cent and the nonprotein nitrogen 27.0 mg. per cent.

Penicillin throat spray was administered every two hours beginning on January 28. Penicillin for intramuscular use as a prophylactic treatment was not available for civilians at that time. Intravenous sulfadiazine was begun on the day of operation and continued for five days.

On January 30, the diverticulum of the esophagus was excised in one stage. An incision was made along the anterior border of the sternocleidomastoid muscle in the left

## PHARYNGO-ESOPHAGEAL DIVERTICULA

side of the neck. The platysma muscle was incised and one or two superficial veins were tied and cut. It was not necessary to divide the omohyoid muscle or the inferior thyroid artery. The diverticulum was found readily. It was a rather large one with a large opening. It was removed and the layers of the posterior pharyngeal wall were approximated with fine silk. The sutures in the mucosal layer were tied on the inside. The edges of the muscularis were then approximated and a third layer of sutures was used to roll the sutured portion in. Because of the difficulty of securing a perfectly dry field, a drain was brought out through the lower end of the incision, to be removed in 24 hours, and the wound was closed with silk.



FIG. 4.—Case 2: Roentgenogram showing a medium-sized pulsion diverticulum of the pharyngo-esophageal junction. Oblique view showing orifice of the sac.

Pathologic examination of the specimen showed a soft, gray-red sac, measuring 4.0 x 2.5 x 1.0 cm. The serosa was injected. The inner lining of the sac was made up of soft, gray, glistening, plicated mucosa. A 1-cm. area of the mucosa was dark gray and mottled with discrete spots of injection, but there was no induration. The wall of the sac measured up to 2 mm., but there was thickening of the distal wall up to 5 mm.

The patient's postoperative course was uneventful. The wick was removed on the day following operation and the sutures were removed eight days after operation. She was discharged from the hospital in excellent condition, with the wound well healed on February 12.

Case 2.—M. G. H. No. 504276: J. R., male, age 47, was admitted to the Baker

Memorial Hospital on September 17, 1945. He had first noticed about four years previously that when he bent his neck or leaned forward, particles of previously eaten food appeared in his mouth. He was conscious of excessive mucus in his throat at night. There was no choking, however, or difficulty in breathing. Sometime after this he began to cough up food and have difficulty in swallowing large mouthfuls. A roentgenologic examination in 1944 had been negative, but, in July, 1945, a diagnosis of diverticulum of the esophagus had been made.

Physical examination was entirely negative. The patient was a well-developed and well-nourished man. Blood pressure 114/68.

Laboratory studies revealed a white blood count of 9900, photo. hemoglobin of 14.7 Gm. The serum protein was 6.9 mg. per cent and the nonprotein nitrogen 27 mg. per cent.

Intramuscular injections of penicillin were begun on the day of admission. The administration of sulfadiazine was likewise started on the day of admission, but the drug was omitted two days later because the patient developed a skin rash.

On September 20, 1945, the esophageal diverticulum was excised. An oblique incision was made in the left side of the neck along the anterior border of the sternomastoid muscle and deepened through the platysma muscle. The omohyoid muscle was retracted downwards. The retropharyngeal space was entered. The diverticulum was found easily. It lay in the usual location. It was of medium size. There was no evidence of inflammatory reaction around it. It was freed up and traction made upon it. The muscularis close to its base was incised exposing the mucosa which was then cut. The mucosal edges were sutured with interrupted No. 3 silk with the knots tied on the inside. The diverticulum was finally removed and the closure of the pharyngeal wall was completed with a single layer of fine silk sutures to approximate the muscular edges. There was almost no bleeding and it was, therefore, decided to close the wound without drainage. This was done using fine silk sutures in the platysma and subcutaneous fat and silk in the skin.

Pathologic examination of the specimen revealed a previously opened sac 2 cm. in diameter with a smooth gray outer surface. The wall was 1 mm. thick. There was a small amount of friable red tissue in the lumen.

The patient's postoperative course was uneventful. He was up out of bed on the 2nd day following operation, the stitches were removed on the 4th day, he was started on a soft solid diet on the 7th day, and discharged from the hospital in excellent condition with the wound well healed on the 9th postoperative day. He reported for examination on October 15th, and was completely symptom-free and ready to return to work.

#### CONCLUSIONS

Although the two-stage operation for the removal of pulsion diverticulum of the pharyngo-esophageal junction represented a definite improvement over the earlier technics used in the performance of the operation in one stage, it is now possible, by observing certain refinements of technic, herein described, and by taking advantage of the protection against infection which results from the prophylactic use of penicillin and sulfadiazine, once more to resume the use of a one-stage procedure which has obvious advantages over the two-stage operation.

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# ANATOMIC DATA REGARDING THE SURGICAL TREATMENT OF ANGINA PECTORIS

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SURGICAL PROCEDURES devised for relief of pain of cardiac origin have involved extensive interruption of preganglionic or postganglionic nerve fibers.<sup>1, 2, 3</sup> This has been accomplished either by section of the white communicating rami of the upper thoracic spinal nerves or by removal of the inferior cervical and upper thoracic sympathetic trunk. Injection of this portion of the sympathetic trunk with alcohol, also, is an accepted method. All these attempts, apparently, have been made without complete or proven anatomic and physiologic evidence of the exact origin of the preganglionic and postganglionic sympathetic neurons or of the exact course taken by the afferent pain fibers of spinal ganglion origin which accompany these sympathetic nerve complexes. Thus, the exact origin of the preganglionic sympathetic fibers which accelerate the heart and dilate or constrict the coronary arteries is of more practical interest than is at first apparent. It is known that all of the cardiac accelerator fibers have their preganglionic origin in the upper thoracic segments. These preganglionic fibers effect synaptic connections with postganglionic neurons in both the cervical and thoracic sympathetic ganglions, and the postganglionics reach the heart *via* the cervical and thoracic cardiac nerves. Cardiac afferent (pain) fibers of spinal ganglion origin accompany the sympathetic cardiac nerves to enter the spinal cord in the upper thoracic region; other cardiac afferent fibers are components of the vagus nerve.

It is the object of this investigation to determine the exact origin of the preganglionic cardiac accelerator fibers. This was done with the aid of a series of experimental procedures involving direct stimulation of the nerve trunks and roots as they issue from the thoracic spinal cord.

## METHOD

Dogs were used as the experimental animals. Under nembutal anesthesia, a laminectomy was performed extending from the seventh cervical to the sixth or seventh thoracic segments. The spinal cord was transected at approximately the eighth cervical segment and again at the seventh thoracic level. The spinal nerves were isolated and a ligature was placed on each nerve at the point of its emergence from the dura. Each nerve was then cut proximal to the ligature

and the length of spinal cord thus separated from its attachments was removed from the body.

A common carotid artery was cannulated and attached to a mercury manometer in such a way as to record variations in pulse rate and blood pressure on a kymograph.

Each spinal nerve, in turn, was picked up, carefully separated from surrounding tissues, its excess moisture removed with a small absorbent cotton

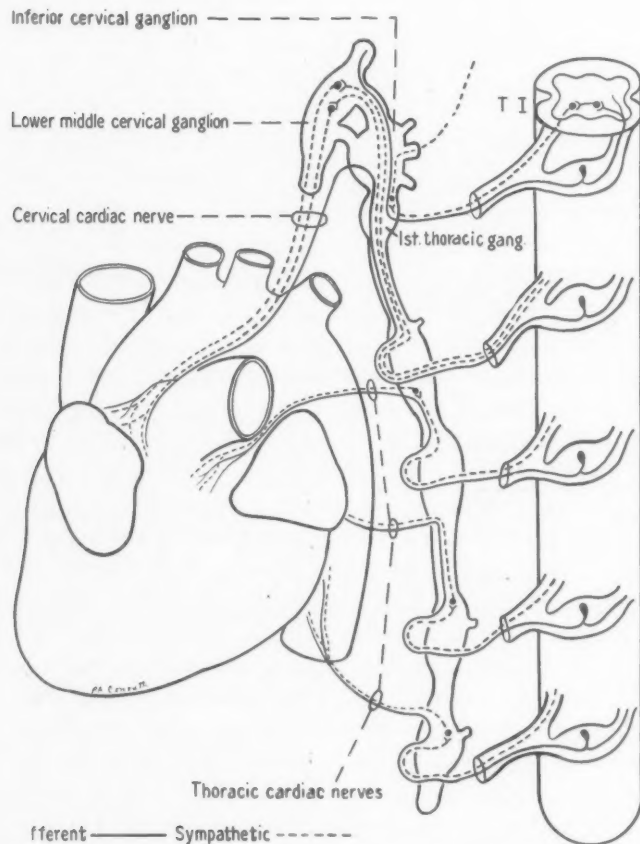


FIG. 1.—Diagrammatic drawing illustrating distribution of sympathetic cardiac accelerator and afferent (pain) fibers.

applicator, and then stimulated with varying strengths of faradic current from a Harvard Inductorium. A coil setting of eight to nine centimeters was found to give the most adequate stimulus. Sufficient time was allowed between successive stimulations for the pulse rate and blood pressure to return to the control level.

At the end of each experiment the segmental origin of every nerve involved in the experiment was confirmed by dissection.

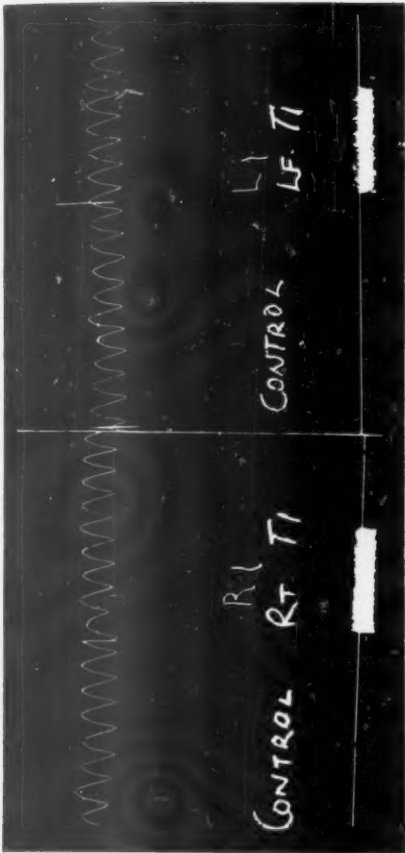


FIG. 2.—Kymographic record showing carotid blood pressure and heart rate changes following faradic stimulation of the first thoracic nerve trunks.

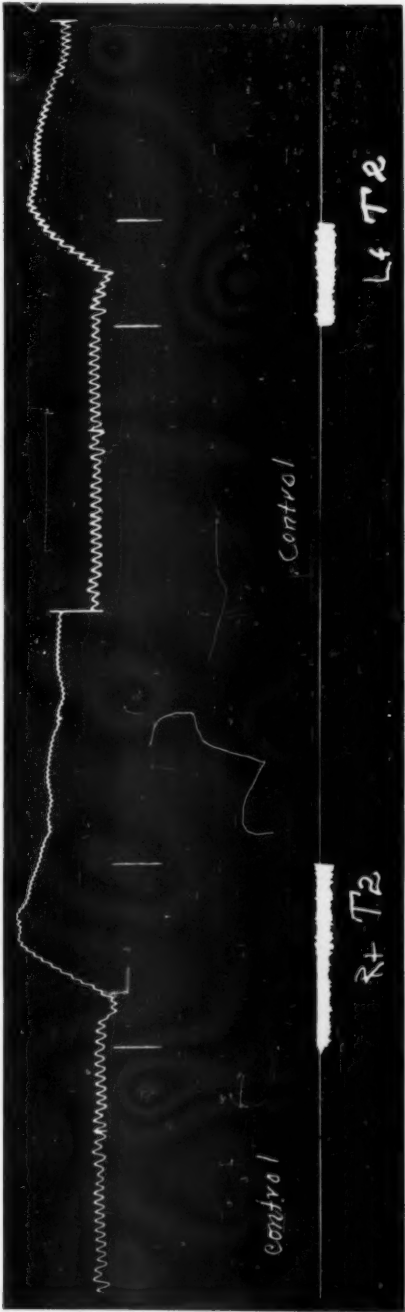


FIG. 3.—Kymographic record showing carotid blood pressure and heart rate changes following faradic stimulation of the second thoracic nerve trunks.

## EXPERIMENTAL FINDINGS

In every animal tested it was found that stimulation of the eighth cervical or the first thoracic spinal nerve failed to elicit any perceptible influence on either the pulse rate or the blood pressure (Fig. 2). This suggests that, if any preganglionic fibers arise from the first thoracic segment and pass through the first white communicating ramus to effect synaptic connections in the sympathetic trunk with postganglionic neurons which reach the heart, they are not numerous enough to elicit a cardiac response under the conditions of the experiment. Increased and decreased strength of stimulus also failed to elicit a response.

In view of these findings, it may be concluded that very few, if any, of the preganglionic fibers of the first thoracic segment are cardiac accelerator fibers.

In the second thoracic nerve, however, the weakest effective stimulus

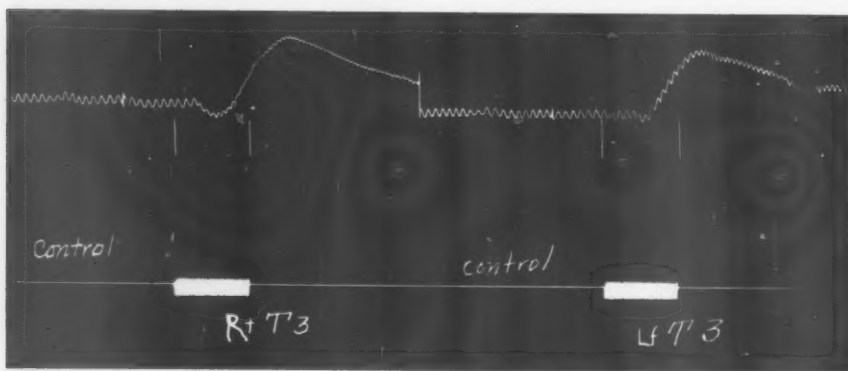


FIG. 4.—Kymographic record showing carotid blood pressure and heart rate changes following faradic stimulation of the third thoracic nerve trunks.

elicited a very marked rise in blood pressure and an equally striking acceleration of pulse rate (Fig. 3). The response from the third thoracic nerve was of approximately identical strength and duration (Fig. 4). Stimulation of the fourth, fifth and sixth thoracic nerves resulted in progressively diminishing acceleration effects, but the effect on blood pressure elevation was remarkably consistent at all these levels (Figs. 5 and 6). The constant pressure response probably is due to stimulation of the splanchnic nerves. These preganglionic neurons are present in the spinal nerves from the fourth or fifth through the twelfth thoracic segments, and upon stimulation are thought to elevate systemic blood pressure by constricting the vessels of the so-called "splanchnic bed."

In the first series of experiments the spinal nerves were isolated and stimulated on only one side in each animal. In some of these animals the stimulation was carried out on the left side; in others on the right. Comparison of the records revealed very plainly that in those animals whose left spinal nerves were stimulated the rise in blood pressure was much more striking than the

acceleration of the pulse rate; in those whose right spinal nerves were stimulated the acceleration of pulse rate was marked but there was only a slight rise in blood pressure. In two animals the spinal nerves on both sides were isolated at the same time and subjected to stimulation. In these experiments it was found that this same difference in reaction was present on the two sides of the same animal and, thus, was not simply a variation in reaction from animal to animal nor the result of slight difference in technic (Figs. 4 and 5).

To investigate any possible effect of antidromic conduction the sensory and motor roots were separated in one animal and stimulated separately. Stimulation of the sensory root failed to elicit any response, while stimulation of the motor root alone produced a response identical with that resulting from stimulation of the whole spinal nerve (Fig. 7).

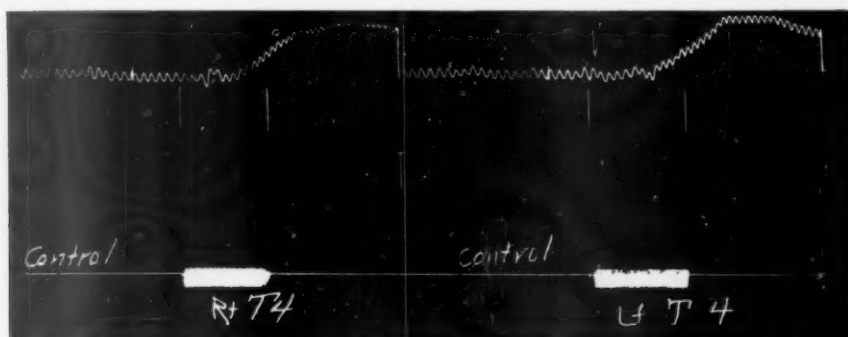


FIG. 5.—Kymographic record showing carotid blood pressure and heart rate changes following faradic stimulation of the fourth thoracic nerve trunks.

DISCUSSION.—In the present series of experiments stimulation of the roots of the second to the sixth thoracic nerve roots readily elicited both cardiac acceleration and increased carotid pressure, but stimulation of the eighth cervical and first thoracic spinal nerves failed to elicit any change in heart rate or carotid pressure. These results apparently indicate that the first thoracic nerve conveys no preganglionic cardiac accelerator fibers (Fig. 1).

Unpublished anatomic evidence derived from a series of experiments intended to determine the exact course of afferent cardiac fibers which accompany the cervical and thoracic cardiac sympathetic nerves indicates that most of the afferent fibers of spinal ganglion origin descend in the sympathetic trunk to enter the thoracic spinal nerves through communicating rami below the first thoracic segments. Apparently, then, the afferent fibers from the heart take the same course as the efferent sympathetic cardiac accelerator fibers; that is, none of them pass through the first gray or white communicating rami.

The marked difference in response to stimulation of the left and the right cardiac sympathetic nerves confirms a portion of the findings reported by Fogelson.<sup>4</sup> This investigator noted that, although the cardiac sympathetic



nerves on either side had the combined effect of accelerating the heart rate and raising the blood pressure, stimulation of the right cardiac sympathetics elicited a greater acceleration response, while stimulation of the left cardiac sympathetics influenced principally the volume of ventricular output.

Anrep and Segall,<sup>5</sup> in an apparently excellent investigation on cardiac physiology, advanced the opinion that sympathetic cardiac acceleration is accompanied by coronary vasodilatation. This conclusion seems logical, but subsequent studies afford overwhelming evidence in favor of the opposite view—namely, that stimulation of the sympathetic system, though it accelerates the heart rate, causes an increase in the tone of coronary vessels.

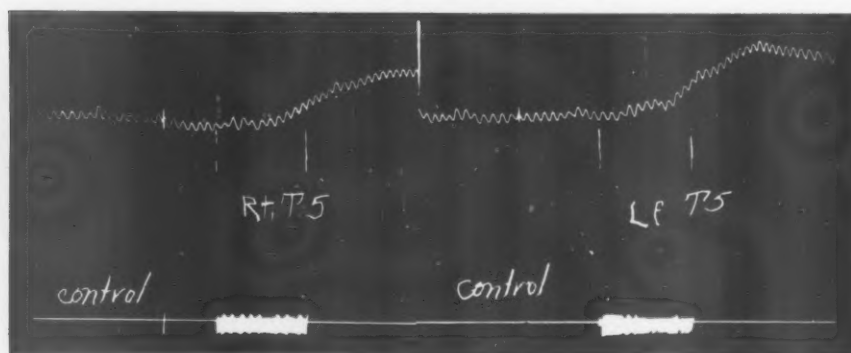


FIG. 6.—Kymographic record showing carotid blood pressure and heart rate changes following faradic stimulation of the fifth thoracic nerve trunks.

Kountz, Pearson and Koenig,<sup>6</sup> in experiments with revived human hearts, found that when the heart was beating strongly and with the normal A-V association, stimulation of the inferior cervical ganglion reduced the flow into the coronary arteries at the same time it increased the heart rate. Only when there was dissociation of atrial and ventricular contractions did sympathetic stimulation increase the coronary flow. Under this latter circumstance, ventricular rate was unchanged by sympathetic stimulation.

Katz and Jochim,<sup>7</sup> in their experiments with isolated dog hearts, concluded that sympathetic nerves carry both adrenergic vasodilator and vasoconstrictor fibers, with the latter predominant. They also observed that when the spinal cord was cut to release the sympathetic system from central nervous system influence there resulted a definite coronary vasodilatation, thus, strongly implying that tonic constriction is mediated *via* sympathetic fibers of the same origin as those which carry accelerator impulses. They concluded that if the coronary innervation in man is similar to that in the dog, then sympathetic denervation in man may not only interrupt afferent pain fibers, but the only efferent vasoconstrictor fibers as well.

Raney<sup>8</sup> states that, whether the sympathetic postganglionic fibers constrict or dilate the coronary vessels normally, it is very probably that their action in

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certain pathologic states of the vessel walls is to constrict the vessels so markedly as to produce ischemia of the cardiac muscle.

All of the literature to date, then, seems to indicate that the interruption of sympathetic accelerator and vasomotor fibers, and afferent fibers of spinal ganglion origin, would bring about an increase in coronary blood flow and at the same time materially lessen the pain of any subsequent anginal attacks. Since the sympathetic cardiac acceleration fibers and cardiac afferent fibers of spinal ganglion origin have no anatomic relationship with the first thoracic nerve, probably most sympathetic coronary vasomotor fibers also arise below the first thoracic nerve. If this is the case, then section of the sympathetic trunk below the first thoracic sympathetic ganglion with removal of the second, third

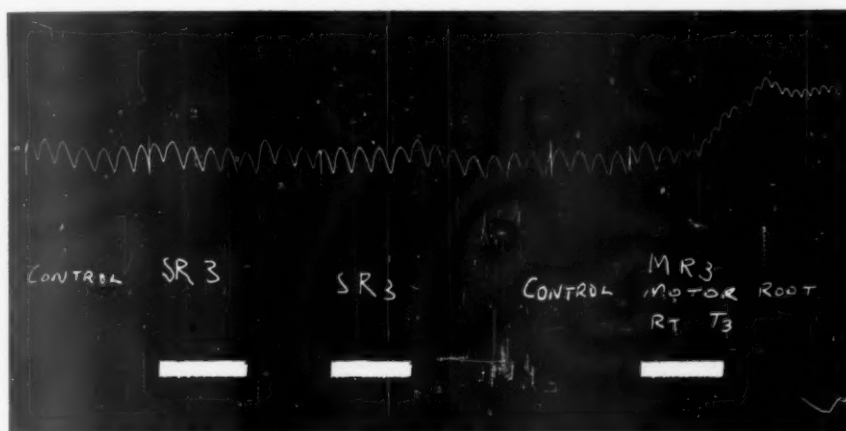


FIG. 7.—Kymographic record showing carotid blood pressure and heart rate following faradic stimulation of the right third thoracic sensory root (SR. 3.) followed by stimulation of the motor root (MR. 3.) of the same segment.

and fourth sympathetic ganglions would result in complete denervation of the heart. Carefully controlled alcohol injection of the second, third and fourth sympathetic ganglions would produce the same results with less surgical trauma. Since the pain of anginal attacks is usually unilateral and on the left side, thoracic sympathetic ganglionectomy on that one side only should result in favorable relief of pain and cardiac ischemia.

Raney<sup>5</sup> has described a series of operations for angina in which he has used a procedure virtually identical with the one we would suggest if anatomic and physiologic conditions in man are similar to those of the dog. He reports 100 per cent relief in all 11 of the patients so treated.

From our findings, we believe that either extirpation or alcohol injection of the second to the fifth thoracic sympathetic ganglions on the affected side only would result in complete or marked alleviation of coronary spasm and virtually complete relief from pain in subsequent anginal attacks. Concluding, from our experiments, that the eighth cervical and first thoracic segments do not contribute to cardiac innervation, it, thus, becomes apparent that effective cardiac

denervation may be achieved without disturbing the inferior cervical and first thoracic ganglions and their communicating rami—in this way leaving intact part of the pathways for sympathetic responses in the head, neck and upper extremity.

## SUMMARY

In dogs from which a length of spinal cord had been removed, stimulation of the isolated spinal nerves was observed to produce cardiac acceleration and a rise in systemic blood pressure when the second through the sixth thoracic spinal nerves were stimulated. No change in heart rate or blood pressure was observed when the eighth cervical or first thoracic spinal nerves were stimulated, indicating that these segments do not convey any cardiac efferent fibers.

The effect in pulse rate was most marked in the second and third thoracic nerves, with diminishing effect in the fourth and fifth and only very slight effect below the fifth thoracic nerve. The effect on systemic blood pressure was more or less constant from the second thoracic down as far as the seventh thoracic nerve.

Attention is called to the implications of this information as the anatomic basis for a more scientific surgical treatment of angina pectoris. By means of surgical removal or alcohol injection of the second, third and fourth thoracic sympathetic ganglions on the affected side only, a complete alleviation of anginal pain and a reduction of coronary vasospasm should result. This single surgical procedure does not completely interrupt the pathways of sympathetic effector impulses to the head and upper extremity, since the first thoracic segment which conveys fibers to these areas, but which does not convey cardiac afferent or efferent fibers, remains intact.

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## A TEN-YEAR SURVEY OF INTESTINAL OBSTRUCTION

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RECENTLY a review was carried out of all cases in which the diagnosis of intestinal obstruction was made on the Service of the senior author at the Hospital of the University of Pennsylvania during the ten-year period, 1934-1943. It was hoped that two things could be accomplished by such a survey. First, certain well-recognized features of intestinal obstruction could be reemphasized, *e.g.*, the high mortality associated with strangulation, advanced age, delayed treatment, *etc.* Second, we hoped to obtain statistical evidence to support a clinical impression that the mortality in intestinal obstruction has been reduced in the past ten years by improved treatment, the use of intestinal suction-drainage by means of the Miller-Abbott tube being an important factor. During this ten-year period, there were 292 cases who were admitted with either the primary diagnosis of obstruction or who developed this as a complication during their hospitalization. The importance of intestinal obstruction is demonstrated by the fact that 17 per cent of all surgical deaths at the Philadelphia General Hospital resulted from this condition.

In our survey the youngest patient was six weeks old, the oldest 84 years. Chart I shows the distribution by decades. The average age of all 292 cases was 45 years. Of the group who survived, the average age was 44 years, of those who died, 59—a difference of 15 years. This bears out the fact that the older patient with intestinal obstruction has a poorer chance for survival than the younger one. Carcinoma accounts for a high percentage of cases of obstruction in the older age-group. The nature of the disease in itself contributes further to the increased mortality in this group.

The cases were about equally divided between males and females, 48 per cent and 52 per cent, respectively (Table I). However, the mortality among the males was 14 per cent and among the females 9 per cent. The higher mortality in the former group is to be explained in part at least by the cases of lymphopathia venereum. Though this disease accounted for many cases of obstruction among the females, no deaths resulted from it, and during this period no cases of rectal stricture attributable to this disease were seen in the male.

A little more than half (60 per cent) were only partially obstructed (Table II). The mortality in this group, however, 10 per cent, was only slightly lower than in those who had complete obstruction, 12 per cent. One might have anticipated a lower mortality in those only partially obstructed, but, once again, the mortality in this group was increased because of the cases of carcinoma included therein. The cases were quite evenly divided between those in whom the disease was acute and those in whom it was chronic (Table III). The mortality in the two groups was exactly the same, 11 per cent, which corre-

sponded to the mortality for the entire series of 292. The nature of one of the important etiologic factors in chronic obstruction, *i.e.*, carcinoma, balances the seriousness of acute obstruction.

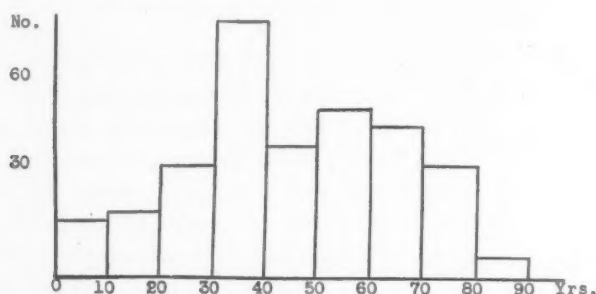


CHART I.—Distribution of cases by decades.

In the acute series, the average duration of symptoms for those who died was 2.6 days and for those who lived, 2.3 days (Table IV). There is no significant difference between these two figures. This is at variance with the

TABLE I

	SEX	No.	Died	Mortality
Females.....		153 (52%)	13	9%
Males.....		139 (48%)	19	14%

TABLE II

	DEGREE OF OBSTRUCTION		
	No.	Died	Mortality
Partial.....	176 (60%)	18	10%
Complete.....	116 (40%)	14	12%

TABLE III

	DURATION OF SYMPTOMS		
	No.	Died	Mortality
Acute.....	153 (52%)	17	11%
Chronic.....	139 (48%)	15	11%

generally accepted fact that the mortality for a group of cases with delayed treatment is higher than in a similar group with early treatment. About ten years ago a review of intestinal obstruction similar to this one was carried out at the Hospital of the University of Pennsylvania. Comparable figures obtained in the earlier survey showed that the average duration of the disease in those who died was 2.1 days and in those who lived, 1.2 days, a result which would be anticipated. In comparing the figures in these two series one may be justified in inferring that some cases with delayed treatment are now being salvaged who previously would have died. As more and more cases are saved



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in spite of delayed treatment, the average duration of symptoms for those surviving will increase and tend to make this figure approach more closely that of the group in whom death results. The average delay of 2.5 days before hospitalization in this series is still too long and unnecessarily increases the mortality in acute obstruction. Unfortunately, delay sometimes occurs even after admission to the hospital. In the face of a typical history and findings on

TABLE IV  
ACUTE CASES

### AVERAGE DURATION OF SYMPTOMS

	Previous Series	Present Series
Lived.....	1.2 days	2.3 days
Died.....	2.1 days	2.6 days

TABLE V  
SITE OF OBSTRUCTION\*

	No.	Died	Mortality
Small bowel.....	184	14	8%
Large bowel.....	114	18	16%

\* Some cases showed multiple points of obstruction.

TABLE VI  
CAUSE OF OBSTRUCTION

	No.	Died	Mortality
Adhesions.....	79 (27%)	4	5%
Malignancy.....	59 (20%)	20	34%
Lymphopathia venereum.....	41 (14%)	0	0%
Inguinal hernia.....	41 (14%)	2	5%
Femoral hernia.....	13 (4%)	4	31%
Ventral hernia.....	8 (3%)	0	0%
Internal hernia.....	5 (2%)	1	20%
Others.....	46 (16%)	1	2%

physical examination suggesting intestinal obstruction, one should not defer treatment if a typical roentgenogram is not found. The burden of the diagnosis and the resultant decision as to treatment should not be placed solely on the roentgenologist.

The mortality for those having small bowel obstruction, 8 per cent, was only half that in which the large bowel was involved, 16 per cent (Table V). Carcinoma of the large intestine no doubt accounts for the higher mortality in the latter group.

The commonest causes for obstruction were adhesions, malignancy, and hernia, accounting for 63 per cent of the cases (Table VI). The differences in mortality among the various groups were striking. Malignancy accounted for 20 per cent of the cases of obstruction, and 34 per cent of these died. Adhesions accounted for 27 per cent of the cases in this series, but only 5 per cent of these died. One should not infer from these figures that the mortality during this period for carcinoma of the large bowel was 34 per cent. Many

cases with this disease were admitted without evidence of significant obstruction and do not, therefore, appear in this collection.

Of the 292 cases in this series, 33 (11 per cent) were instances of post-operative obstruction.

No case with lymphopathia venereum died. The procedure carried out in this disease was usually a palliative one, such as a simple loop-colostomy or a Lahey-type of colostomy.

TABLE VII  
COMPARISON OF CAUSE OF OBSTRUCTION AND MORTALITY

	Per Cent of Series	Per Cent of Deaths
Malignancy.....	20%	63%
Femoral hernia.....	4%	13%
Adhesions.....	27%	13%
Inguinal hernia.....	14%	6%

TABLE VIII  
COMPARATIVE MORTALITY OF OLD AND NEW SERIES

Cause	Series	Mortality
Hernia.....	Previous	25.9%
	Present	10%
Adhesions.....	Previous	20.4%
	Present	5%

Twenty-three per cent of the cases were obstructed on the basis of a hernia. The inguinal region was the most common site, and carried a mortality of only 5 per cent. In contrast, the mortality in the femoral hernia group was very high—31 per cent. Failure to recognize promptly the nature of the disease is prone to occur in a femoral hernia, especially if a Richter's-type is present or if the patient is obese. At operation, one should never hesitate to divide the inguinal ligament if necessary to reduce the hernia. Also it is sometimes of value to expose the bowel from above by extending the wound and entering the peritoneal cavity through a muscle-splitting incision. Failure to follow these two suggestions leads at times to unnecessary trauma or rupture of an already strangulated intestine causing further contamination of the peritoneal cavity and increased operative mortality.

Ninety-two per cent of the deaths resulted in cases of obstruction due to malignancy, femoral hernia, inguinal hernia and adhesions (Table VII). Malignancy accounted for 20 per cent of the cases, but 63 per cent of the deaths. Femoral hernia accounted for 4 per cent of the cases, but 13 per cent of the deaths. These two conditions, therefore, were responsible for 24 per cent of the cases of obstruction, but 75 per cent of the deaths.

Comparison of the present series with the previous review of intestinal obstruction at this hospital reveals a definite improvement in the prognosis (Table VIII). In the earlier series the mortality in obstruction due to hernia was 25.9 per cent; in the present series it was 10 per cent. For obstruction due to adhesions, the mortality in the earlier group was 20.4 per cent—in the latter, 5 per cent.

# INTESTINAL OBSTRUCTION

Seventy-four cases (25 per cent) showed evidence of strangulation at the time of operation; only 12 per cent of the group died (Table IX). The mortality in similar groups in the previous review ranged from 40-60 per cent. The lower mortality in the present series is related, we feel, to improved methods of treatment and probably also to the fact that the surgery was performed by a relatively small group of men, all with adequate training or supervision. The figure for the Philadelphia General Hospital series, for example, is compiled from statistics on the work of some 50 or 60 surgeons, of varied ages and degrees of experience.

TABLE IX  
STRANGULATION

	No.	Died	Mortality
Present series.....	74 (25%)	9	12%
M. G. H.....			40%
N. Y.....			55%
P. G. H.....			60%

TABLE X  
MORTALITY

	No.	Died	Mortality
Total.....	292	32	11%
Resected.....	53 (18%)	10	19%

As might be expected, the mortality in that group of cases in which resection was required, was almost double that of the total series, 19 per cent *versus* 11 per cent (Table X).

If one omits the cases of malignancy (which account for 20 of the 32 deaths in this series) and the cases of strangulation (which account for nine of the 32 deaths) then the mortality in the remaining group of 159 cases of obstruction is only 1 per cent (three deaths). The prognosis, therefore, is excellent if a patient is admitted with obstruction, but has no evidence of malignancy or strangulation.

The causes of death are listed in Table XI. Peritonitis, malignancy, pulmonary embolism, pneumonia and cardiovascular-renal disease account for 84 per cent of the deaths. Two of the cases in this series were moribund at the time of admission, and would not respond sufficiently to supportive treatment to permit operation.

Suction drainage of the gastro-intestinal tract by means of the Jutte, Levin or Miller-Abbott tube was carried out in 124 of the 292 cases as an adjunct in the treatment. In general, it has been reserved for the more serious cases. Our clinical impression was that this procedure was of value in 80-90 per cent of the cases in which it was used. Twenty-five per cent of the cases in which suction drainage was carried out required no subsequent operative procedure. Obstruction developing in the postoperative case on the basis of fresh adhesions is a particularly fertile field for correction by intubation without the necessity for subsequent operation.

During the three-year period, 1934-1936, suction drainage was carried out in 26 cases by means of a Jutte or Levin tube placed in the stomach. Eight of these cases succumbed, a mortality of 31 per cent (Table XII). In 1937 the Miller-Abbott tube became available for intubation and decompression of the small intestine. During the seven-year period, 1937-1943, this tube was used in 65 instances of obstruction, with ten deaths, a mortality of 15 per cent. Another 33 cases were treated by gastric suction drainage by means of the

TABLE XI

## CAUSE OF DEATH

	No.	Per Cent
Peritonitis.....	8	25%
Carcinomatosis.....	7	22%
Pulmonary embolism.....	5	16%
Pneumonia.....	4	13%
Cardiovascular-renal disease.....	3	9%
Others.....	5	16%

TABLE XII

## SUCTION-DRAINAGE

	No.	Died	Mortality
1934-1936 (prior to M. A. tube).....	26	8	31%
1937-1943 (after M. A. tube).....	98	15	15%

TABLE XIII

## TOTAL SERIES

	No.	Died	Mortality
1934-1936 (prior to M. A. tube).....	74	13	18%
1937-1943 (After M. A. tube).....	218	19	9%

Jutte or Levin tube, with five deaths. During this seven-year period, following the introduction of the Miller-Abbott tube, therefore, there were 98 cases in which suction-drainage was used, with a mortality of 15 per cent, in contrast to the mortality of 31 per cent prior to the introduction of the Miller-Abbott tube. The over-all mortality figures for these same periods reflect this drop in mortality also (Table XIII). We would like to point out, again, that suction-drainage is not routinely used in all cases of obstruction, but is reserved for those more serious cases in which it seems indicated. The last figure also shows that the over-all mortality during the last seven years is 9 per cent *versus* 11 per cent for the entire ten-year period, indicating the trend toward continued improvement in mortality in the latter part of this series.

Though a sharp fall in mortality was associated with the introduction of the Miller-Abbott tube, the improvement in prognosis must not be attributed to use of the tube alone.

Though intravenous fluids were available prior to the introduction of the Miller-Abbott tube, the derangement in body chemistry and fluid balance in intestinal obstruction was never as fully appreciated, or combated, as in

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recent years. Intravenous fluids are being used more freely than ever before, and repeated determinations of the blood chemistry are carried out to aid in determining the amount and kind of fluids required.

During the period of this survey the blood bank was established at the Hospital of the University of Pennsylvania. As a result, there is a supply of readily available blood and plasma at all times. In cases of strangulation with loss of blood and plasma into the areas of involved intestine, a shock-like picture may result, and the condition of the patient can be much improved by infusions of blood and plasma. Cases requiring prolonged operation or resection of the bowel can be carried through the operation in much better condition if such is administered during the procedure. In cases of prolonged illness, on the basis of partial obstruction or carcinoma, the nutrition of the patient may be poor and the plasma protein and hemoglobin values can be raised by transfusion. The value of transfusion as a tonic in a prolonged illness is not to be overlooked.

During the latter half of this survey, the services of a medical anesthetist were obtained by the hospital, and a program of training residents in anesthesia was introduced. At all times, therefore, we have available anesthesia of the type best suited for the individual case, and the free use of intravenous therapy during operation, under supervision of the anesthetist, is a distinct aid in carrying the patient through the procedure in a more satisfactory condition.

Another factor of great importance in these patients was the introduction of the chemotherapeutic agents—the sulfonamide drugs. They have been of value especially in those cases in which peritonitis from contamination by the fecal stream has been a threat. During the postoperative course they have also been of help in combatting pulmonary infections so that now a postoperative fatality from pneumonia alone is uncommon.

In 18 per cent of the cases in which the Miller-Abbott tube was used we were unsuccessful in getting it to pass into the small intestine. More recently, we have failed in less than 10 per cent. These figures represent the efforts of several people, some of whom have had little experience in passage of the tube. In some of these cases of failure, persistent effort would no doubt have been successful in passing the tube, but the condition of the patient did not justify further delay in operative intervention.

In acute mechanical obstruction, if one is unsuccessful in passing the tube promptly, the question arises as to how long one should persist in the attempt. In general, if one is not successful after six hours, as shown by roentgenographic evidence of progress of the tube, decrease in distention, disappearance of pain, and slower pulse rate, then operation is indicated. If one delays too long in attempts to pass the tube, the patient becomes exhausted, the pulse rate rises and peristalsis disappears. Such a patient has become a poor surgical risk.

In the face of marked distention which cannot be handled by intubation for any reason, a Witzel enterostomy in the left lower quadrant, under local anesthesia and a muscle-splitting incision, still remains the procedure of choice and will give excellent results in most cases. In one report, 86 per cent of the cases of



obstruction following operations for appendicitis were corrected by enterostomy alone.

There is no doubt that the value of the Miller-Abbott tube increases in proportion to the experience and skill of the individual who is passing the tube. One man in the hospital who has had a wide experience in use of this tube has been successful in 75 of the last 76 attempts. The one failure might have been avoided had further delay in operation been warranted. Though passage of the tube can be accomplished in the patient's room, fluoroscopic guidance is a distinct advantage, and often saves much time, since any error in direction of the tube into the duodenum can promptly be corrected. Use of a stylet in the tube or mercury placed in the balloon may aid in more rapid passage of the tube into the duodenum. Once the tip of the tube reaches the second portion of the duodenum, the balloon can be inflated with air and further passage of the tube to the point of obstruction is usually accomplished without difficulty. Occasionally gastric distention recurs while the tube is in the small intestine. This can easily be cared for by placing a Levin tube in the stomach and emptying it by suction. If delay in operation is not justified or if the tube fails to pass and operation is necessary, it is frequently possible during the operation to pass the tube manually from the stomach into the small intestine, and thereby obtain postoperative decompression of the intestinal tract.

At operation, in which a Miller-Abbott tube has been passed, one often finds the small intestine pleated or accordionized on the tube. When removal of the tube is indicated the balloon must be deflated and the tube withdrawn slowly, usually six inches every 15-30 minutes, in order to avoid the possibility of retrograde intussusception.

This tube is a useful adjunct in the treatment of intestinal obstruction but cannot replace surgery in all cases. Certain cases of intestinal obstruction are not candidates for intubation and if used improperly, leading to delay in operation, this maneuver may actually be of harm, giving rise to increased mortality.

Large bowel obstruction requires decompression by operative intervention and should not be attempted by intubation. The Miller-Abbott tube often will not pass into the large bowel, and if it does, the contents of this part of the intestine may be too thick to be drained adequately through the small lumen of the tube. If the ileocecal valve is competent, a closed loop-type of obstruction is present. This is very serious and requires prompt correction. If small bowel distention also is present, this can be handled by intubation. Operative decompression of the large intestine is not thereby avoided, however, and following operation, the small bowel distention is automatically corrected, so intubation in these cases is usually unnecessary.

Strangulation is a strict contraindication to delay in surgery in an attempt to intubate the small intestine. Constant severe pain with exacerbations requiring morphine, tenderness, and perhaps a tender mass, tachycardia and leukocytosis, should be warning signs to prepare the patient for operation as promptly as possible. If the strangulation has progressed to an irreversible

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stage, so that resection is necessary, the procedure of choice must be determined at the time of operation—either a double-barrelled enterostomy or primary anastomosis. If primary anastomosis is carried out and the site of repair is under any question, the anastomosis may be temporarily exteriorized or a proximal enterostomy may be performed. A procedure preferable to either one of these, however, we feel, is passage of the Miller-Abbott tube to a point proximal to the site of the anastomosis. Satisfactory decompression of the bowel can be maintained in this fashion and the suture line protected against distention during the early stages of healing. Fluids by mouth can be administered during this time, since the tube will remove all fluid and gas before they reach the site of anastomosis.

### SUMMARY

- (1) A statistical review of 292 cases of intestinal obstruction is presented.
- (2) The average age of those who survived was 44 years, and of those who died, 59 years.
- (3) The mortality did not seem to be influenced by whether or not the obstruction was complete or partial, acute or chronic. Improvement in operative technic and pre- and postoperative care probably account for this.
- (4) The mortality in small bowel obstruction was one-half that of large bowel obstruction.
- (5) Thirty-four per cent of the cases of obstruction due to malignancy succumbed.
- (6) Thirty-one per cent of the cases of obstruction due to femoral hernia died. This is in contrast to a mortality of 5 per cent in the cases due to inguinal hernia.
- (7) The mortality in the group showing strangulation was only 12 per cent.
- (8) If resection is necessary, the mortality is almost doubled.
- (9) The over-all mortality in this series was 11 per cent. If the cases of malignancy and strangulation are excluded, the mortality in the remaining 159 cases in this series is 1 per cent.
- (10) Following the introduction of the Miller-Abbott tube, the mortality in this series was reduced by one-half. Other factors, including transfusion, chemotherapy and improvement in anesthesia, unquestionably, contributed to this decrease in mortality.

## TRAUMATIC PANCREATITIS\*

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THE SERUM AMYLASE TEST and the trend toward conservative management of acute pancreatitis represent the two recent advances which have widened the recognition of this disease, rendered its diagnosis more certain, and greatly reduced its mortality. Within the past four years 28 cases of acute pancreatitis have been encountered in the Jefferson Medical College Hospital, 20 of the edematous type and eight of the hemorrhagic type. In these, a conservative nonoperative method of treatment<sup>1</sup> was generally employed, reserving operation for the complications, namely, pseudocyst and abscess,<sup>2</sup> or for associated biliary tract disease. One case from this series is unique in that it followed a nonpenetrating upper abdominal injury. It afforded an unusual opportunity to apply the more recent concepts of diagnosis and treatment to a seldom-recognized and rare type of pancreatitis. Because of the sustained extremely high serum amylase values and the recovery without complications following conservative therapy, we are reporting the case in detail.

**Case Report.**—D. M., male, age 8, was admitted to the Jefferson Medical College Hospital, September 10, 1945, with the chief complaint of upper abdominal pain.

On September 1, 1945, nine days before admission, the patient fell from a bicycle, striking his upper abdomen on the handle-bars. This was followed by constant moderate upper abdominal pain, not accompanied by nausea or vomiting. On the following day the pain still persisted, accompanied by nausea and one episode of vomiting. He took only liquids and remained in bed all that day and the two succeeding ones. At no time was the pain severe enough to prevent sleep. Except for the first day after the accident the boy's appetite remained good and there were no nausea or vomiting. On the fourth day, because of the persistent mild upper abdominal pain, the family doctor referred the patient to the accident ward with a presumptive diagnosis of appendicitis. Examination at that time revealed a healthy looking boy with normal temperature, pulse and respirations. There was slight tenderness in the right upper and right lower abdominal quadrants and questionable muscle spasticity on this side which could be easily overcome. Rebound tenderness was absent and the rectal examination was negative. The white cell count was 9,000. He was referred to the care of the children's out-patient department.

The following day, the fifth after injury, the boy was free of pain and resumed moderate activity at home. During the ensuing three days the patient remained free of pain, had a good appetite, normal daily bowel movements, and normal color of the urine.

On the morning of the day of admission, nine days after injury, the boy was awakened from sleep by a severe constant periumbilical pain which radiated to both hypochondria. This pain caused him to remain very quiet in bed, doubled up. It was even more severe when he attempted to walk. There was no associated nausea or vomiting. He did not experience shoulder-top or back pain. At no time was blood noted in the stools or urine. Because of the constant severe upper abdominal pain the child was again brought to the hospital.

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\* Presented before the Atlantic County Medical Society, December 14, 1945.

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*Physical Examination.*—The patient was a well-nourished boy lying with his knees and thighs flexed, complaining of abdominal pain. Temperature 100° F.; pulse 130; respirations 30; and blood pressure 100/70. The face was flushed but not cyanotic. The heart and lungs were normal. On inspection, the abdomen was scaphoid and showed no evidence of external injury. Diaphragmatic excursions were not visible and respirations were entirely thoracic. There were exquisite tenderness, rebound tenderness, and board-like rigidity in the entire upper abdomen and periumbilical area. There was slight muscle-guarding but no tenderness in the lower abdomen. The costovertebral angles were not tender on percussion. There were no visible or palpable abdominal masses. Peristalsis was hypoactive. Rectal examination, as well as the remainder of the physical examination, was negative.

The clinical impression was nonpenetrating upper abdominal trauma with secondary peritonitis.

*Laboratory Data.*—Examination of the blood showed hemoglobin 71 per cent; red cells 4,200,000; white cells 18,000, with polymorphonuclear cells 90 per cent (10 per cent young forms), eosinophils 1 per cent, lymphocytes 8 per cent, monocytes 1 per cent; and platelets 280,000. Urinalysis was negative. The serum amylase was 320 units (normal 80-180 units). A plain roentgenogram of the abdomen was negative.

*Treatment and Progress.*—In view of the nine-day interval since injury, the lack of an urgent indication for immediate surgical intervention, and the elevated serum amylase, a policy of watchful waiting was adopted. The vital readings were determined hourly. Slow intravenous administration of 1,000 cc. of 5 per cent glucose in normal saline was instituted. Because of the absence of nausea or ileus, Wangenstein suction was not deemed necessary. Penicillin was administered hypodermically every two hours, the total 24-hour dose being 100,000 Oxford units. During the ensuing 12 hours the pain decreased in intensity, with sedative drugs withheld; the blood pressure remained within normal limits; the pulse fell to 90, the respirations to 22, and the white cell count to 12,000; the abdominal signs became less marked; and a normal bowel movement occurred.

The following day the boy stated that he still had slight pain but was comfortable. There was a further decrease in the severity of the abdominal signs. The hemoglobin and red blood cell count remained essentially the same as on admission and the white cell count fell to 8,000. The serum amylase rose to 400 units. Since intestinal injury appeared unlikely; since signs of intra-abdominal hemorrhage were lacking; and since pancreatic injury, as evidenced by the abnormally high serum amylase, was sufficient to account for the findings, the conservative policy was continued. A record of the serum amylase fluctuations is shown in Chart 1.

During the first week the patient's condition gradually improved. Liquids and soft foods were well tolerated. The pain gradually disappeared altogether and the signs in the right upper abdominal quadrant subsided; but moderate tenderness, rebound tenderness, and rigidity persisted in the left upper quadrant. During the second week the same type of pain as well as the same physical findings noted on admission recurred. There was still no evidence of any upper abdominal mass. On the 10th day after admission the serum amylase reached a peak of 6,400 units, with a corresponding urinary amylase greater than 1,200 units. Repeated white blood cell counts were normal; repeated routine urinalyses were normal; the blood sugar was 66 mg. (14th day of admission); and the serum calcium was 10.1 mg. (15th day). Roentgenologic examination of the upper gastro-intestinal tract with barium on the 16th day of admission showed no evidence of obstruction and no evidence of extrinsic pressure on the stomach.

During the third week the patient again began to improve, and for the ten days prior to discharge on October 10, 1945, he felt well.

*Follow-up.*—The patient was last reexamined, December 7, 1945, more than three months following the injury. He had remained entirely well following discharge from the hospital. The mother stated that his appetite was excellent and that it was difficult to restrain him from indulging vigorously in sports. Physical examination at this time was



normal. The serum amylase was less than 80 units and blood sugar 80 mg. Roentgenologic study of the upper gastro-intestinal tract with barium was again negative.

**DISCUSSION.**—Although trauma undoubtedly may cause acute pancreatitis, it is responsible for only a small percentage of cases. In Schmieden and Sebening's<sup>3</sup> collected series of 2,137 cases, 62 were of traumatic origin. In Truesdale's<sup>4</sup> series of 54 cases and in the authors' 28, only one could be directly attributed to trauma. From these figures trauma would seem to account for approximately 2-4 per cent of the cases.

Since the first recorded case of injury to the pancreas by Travers<sup>5</sup> in 1827, many single case reports have appeared. Most of these injuries, however, have involved other structures as well, such as the spleen, liver, stomach, bowel, kidney, gallbladder, common bile duct, aorta, vena cava, diaphragm, and lung. Thus, Naffziger and McCorkle<sup>6</sup> encountered associated injury in each of their five cases following nonpenetrating abdominal trauma. There was laceration of the spleen in two, laceration of the spleen and contusion of the kidney in one, laceration of the pylorus and first portion of the duodenum in one, and laceration of the third portion of the duodenum in one. Traumatic pancreatitis without injury to other organs is exceptionally rare. Garre,<sup>7</sup> in 1905, was able to collect only eight such cases from the literature. Schmieden and Sebening,<sup>3</sup> in 1928, found only 20 cases.

Traumatic pancreatitis may follow abdominal injury, either penetrating or nonpenetrating, and also surgical operative injury. The penetrating wounds are most commonly caused by bullets, knives or other pointed objects. Nonpenetrating wounds usually result from blows sustained in falls and fights, or by crushes. The force, whether penetrating or nonpenetrating, is usually anterior, but may be lateral or posterior. Surgical injury may follow operations upon the pancreas itself, as in biopsy or partial pancreatectomy, or on adjacent organs such as the stomach, duodenum, lower end of the common bile duct, or spleen.

Because of its soft parenchymatous and extremely vascular structure the pancreas may be contused or ruptured by what might seem insignificant trauma. Venable<sup>8</sup> classifies rupture as incomplete or complete. According to this author, incomplete rupture is a tear in the pancreas within an intact capsule. Complete rupture includes a tear in the capsule as well. Either type may or may not be associated with hemorrhage. Severance of the duct of Wirsung may occur, adding greatly to the gravity of the injury, and is usually followed by pancreatic fistula if the patient survives. The pancreatitis that develops may be either the edematous or hemorrhagic type. The hemorrhagic type is apt to be followed by pseudocyst or abscess formation.

As in the usual forms of pancreatitis the symptoms and signs are so variable and so inconstant that it is impossible to make the diagnosis definitely on clinical criteria alone. Any trauma to the upper abdomen should arouse suspicion of this lesion. Definite confirmation can be obtained by the serum amylase test, if the reading is well above the high normal of 180 Somogyi units. During the acute stage of pancreatitis values range from several hun-



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dred to several thousand units. In the authors' case the level rose to 6,400 units, which, as far as we are aware, represents the highest value ever reported. It must be borne in mind that symptoms, as well as elevated serum amylase, may follow a latent interval of days or occasionally even weeks. The diagnosis is missed because the condition is not thought of and the serum

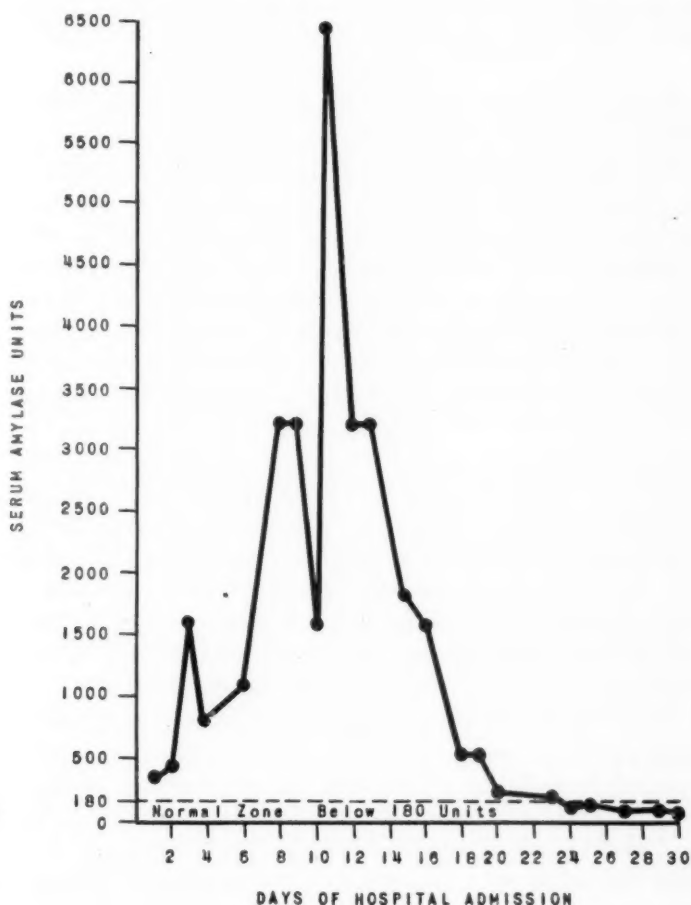


CHART 1.—Serum amylase elevations in authors' case, showing sustained extremely high values.

amylase test is not performed. In the authors' case the serum amylase was elevated on the ninth day following injury and remained elevated for three weeks thereafter (Chart 1).

According to Naffziger and McCorkle,<sup>6</sup> in most cases there is a rapid rise and fall of the serum amylase following pancreatic injury, probably corresponding to the period during which enzymes leak from the injured pancreas. Pinkham<sup>9</sup> believes that a sustained elevation of the serum amylase is suggestive

of the presence of a pancreatic collection. This author urges further clinical observation in such cases in order to derive more data on this point which might aid in the early diagnosis of pancreatic collections. The authors' case in which the serum amylase was sustained at abnormally high levels for three weeks would seem to represent an ideal case for cyst formation, yet this complication did not occur. Obviously the question of the relation of persistent serum amylase elevation to the development of a pancreatic collection can be settled only when many more carefully studied cases are available for analysis.

According to the recent work of Edmondson and Berne,<sup>10</sup> serum calcium findings below 9 mg. per 100 cc. of blood usually occur in cases of pancreatic necrosis some time between the 2d and 15th day of the disease, and values below 7 mg. indicate a fatal prognosis. In the authors' case, on the 15th day of admission, 23 days after injury, the serum calcium was 10.1 mg. at a time when the serum amylase was elevated to 1,600 units. This normal calcium value might be interpreted as indicating pancreatic edema rather than necrosis and certainly was in accord with the favorable outcome of the case.

It is taken for granted that penetrating abdominal wounds associated with pancreatic or other injury should be surgically explored. However, in the treatment of pancreatitis following nonpenetrating abdominal trauma, we believe that the same conservative nonoperative management as recently advocated for the more common forms of pancreatitis is preferable, if injury to important blood vessels and to adjacent organs as the spleen, liver, or gastrointestinal tract can be ruled out. Pancreatic repair is probably greatest when the gland is left undisturbed in a closed abdomen. Since the general reaction and toxemia which may occur result as a rule from primary nonspecific cellular destruction of the pancreas, operation has little to offer. The withholding of food, which acts as a stimulus to pancreatic secretion; Wangenstein suction to combat ileus; oxygen in severe cases; and intravenous administration of saline solution, glucose, amino-acids and vitamins support the patient during the vital period in which the complication of pancreatic collection either infected or noninfected may occur. Chemotherapy in the form of penicillin is a valuable adjunct in preventing secondary bacterial invasion.

If clinical improvement occurs within a few hours and persists, as in the authors' case, it is justifiable to continue a conservative policy of treatment. On the other hand, if the patient's condition becomes progressively worse during the ensuing 4-12 hours, surgical intervention is indicated, for further delay may prove disastrous. Lacerations following stab wounds and tearing injuries may be closed with black silk, but the contused lacerations following nonpenetrating injuries usually cannot be closed. In these instances Penrose drains should be placed in the lesser peritoneal cavity adjacent to the capsule of the injured pancreas and brought to the surface, either through the original incision or a separate one in the flank. The purpose of the drainage is to aid in prevention of diffuse peritonitis or formation of a pancreatic collection (hematoma, abscess, or pseudocyst).

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Pseudocyst formation may occur weeks or months subsequent to the original injury. Pinkham<sup>9</sup> who reviewed recent series of pancreatic pseudocysts states that trauma is responsible for 20 per cent, or less, of the cases. Treatment of these is surgical, consisting of marsupialization of the cyst. Although the authors' case shows no evidence of this complication after three months, continued follow-up study is indicated to exclude it as a very late manifestation of traumatic pancreatitis.

### SUMMARY AND CONCLUSIONS

1. Trauma accounts for approximately 2-4 per cent of cases of acute pancreatitis. Following an upper abdominal injury, acute pancreatitis should always be suspected. A latent period may intervene before appearance of symptoms.

2. Suspicion of traumatic pancreatitis should be confirmed by performance of the serum amylase test, the reliability of which, during the acute phase of pancreatitis, has become firmly established.

3. Operation is not necessary in all cases of pancreatitis following injury. The conservative nonoperative management which has greatly reduced the mortality in the usual types of pancreatitis is advocated for cases following nonpenetrating abdominal injury, if serious injury to other organs and massive hemorrhage can be ruled out.

4. Indications for surgical intervention are penetrating wounds; injury to important blood vessels; injury to adjacent viscera as spleen, liver or gastro-intestinal tract; failure to respond promptly to conservative management; or for subsequent pancreatic collections.

5. A case is presented and discussed in which the diagnosis was suspected clinically, confirmed by the serum amylase test, treated conservatively, and in which recovery ensued without complications.

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## THE SURGICAL TREATMENT OF 1,545 HERNIAE

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IN 1936 a report<sup>1</sup> was made from this clinic on experiences with 500 herniae treated by surgery. This paper presents an account over a five-year period, from 1940 through 1944, inclusive, of 1,545 herniae subjected to operation. The results have been good when early surgical treatment has been initiated. There have been recurrences as well as postoperative complications. This review is undertaken in order to evaluate the procedures employed and to consider what changes in present methods are indicated. The analysis of 1,545 herniae performed covers 1,385 consecutive patients, of whom 770 had indirect inguinal, 205, direct inguinal, 95, recurrent inguinal, 110, femoral, 57, umbilical, 12, epigastric and 136, postoperative ventral herniae. In this series there were 95 postoperative complications and six deaths. There has been a continuous effort to keep the incidence of infection and postoperative pulmonary complications at a minimum, two factors which contribute to recurrences. The deaths in this group were due to complications of the vascular system or infection resulting from delayed intervention.

*General Technic.*—The careful evaluation of every patient with hernia is essential to secure the least possible incidence of postoperative complications which are few in the young adult, but in the extreme age-groups are frequent. Infants with acute herniae require special attention as to fluid balance, and elderly patients, males in particular, require investigation of the lower urinary tract for partial obstruction that may be an etiologic factor in the development of the hernia or in its recurrence after operation. Direct hernia often develops as the result of repeated straining in initiating or maintaining micturition. The large postoperative ventral herniae that contain a fair portion of the abdominal contents are always a problem in preoperative preparation. They require the return of the hernial contents to the abdomen prior to operation by various means including rest in bed for periods up to a week so that the respiratory system will not be embarrassed after operation. Preoperative decompression of the gastro-intestinal tract with catharsis, and postoperative decompression by means of a Miller-Abbott tube or Wangenstein suction have contributed toward keeping distressing and sometimes serious abdominal distention at a minimum.

*Anesthesia.*—Local anesthesia was employed in over two-thirds of all herniae repaired. Postoperative complications were as frequent in the group in which local anesthesia was used as in that in which general anesthesia was used. However, local anesthesia was employed in almost all patients of the older age-group, and it is in this group that the incidence of pulmonary com-

plications is highest. Retching and vomiting, not uncommon after general anesthesia, do place an extra strain on the freshly repaired hernia.

Local anesthesia.....	1,090
General anesthesia.....	397
Local and general.....	37
Spinal anesthesia.....	21

*Suture Material.*—Silk suture material was used in all repairs except 19 in which catgut, and eight in which cotton was employed. It may be said that catgut was limited to the repair of acute herniae in which infection was believed to be present. Cotton has more frequently been used since 1944 and is becoming increasingly popular. There are reports in the current literature that indicate that cotton suture material has many advantages.

*Postoperative Care.*—For the most part, patients operated upon for hernia have been kept in bed for a period of wound healing of 14 days and more. However, the recent trend has been to mobilize patients who possess good anatomic structures, as, for example, the young adult male with a congenital type of indirect inguinal hernia. We think that such patients may be ambulant after operation without much likelihood of recurrence. In those patients whose defects are large or whose structures involved in the repair are of poor quality we maintain that a full period of wound healing is required before any unnecessary strain be placed upon the repair. Likewise, greater attention has been given the protein intake of all patients to correct any deficit in nitrogen balance.

*Inguinal Hernia.*—In a total of 1,070 patients, 1,222 inguinal herniae were repaired. Of these 840 were indirect, 279 were direct and 103 were recurrent.

*Indirect Inguinal Hernia.*—In the majority of instances on this Surgical Service we continue to repair the indirect inguinal hernia in one of two ways. If the structures are good quality and the defect small, a simple anatomic repair without transplantation of the cord is done. As described by Halsted, the sac is dissected up to its neck where it is ligated and transfixed with double medium silk. The stump retracts behind the internal oblique muscle. The cremaster muscle and fascia are drawn up under the edge of the conjoined tendon and the internal oblique muscle in an effort to partially obliterate the inguinal canal. The internal oblique muscle and conjoined tendon are then sutured to Poupart's ligament with interrupted sutures of medium silk so that they closely embrace the cord as it emerges. The margin of the lateral portion of the external oblique is then secured beneath the mesial portion by a series of mattress sutures. The mesial portion of the external oblique is brought to overlap this laterally and secured in a similar manner. Interrupted black silk sutures are employed throughout the procedure.

If the structures are weak or if the defect is large, a Halsted repair with transplantation of the cord to the subcutaneous tissue is done. We have come to use this method more frequently if structures are not good. Discomfort from a cord transplanted to the subcutaneous tissue has been rarely observed. In this procedure all muscular and fascial layers are united beneath the cord, with



the complete obliteration of the old external ring. The new external ring, although nearly opposite the internal ring, is believed to permit recurrence less frequently.

The Bassini operation has enthusiastic advocates among some of the surgeons of the clinic but has not proved as satisfactory as the Halsted operation with transplantation of the cord to the subcutaneous tissue.

In the 840 inguinal herniae the repairs were as follows:

Simple anatomic repair.....	610
Halsted transplant of cord.....	188
Bassini transplant of cord.....	22
Torek procedure, simple repair.....	20

Silk suture material was used in 825, catgut in 8, and cotton in 7 instances. The operation was performed under local anesthesia in 606, general in 216, local supplemented with general in 10, and under spinal anesthesia in 8.

There were three deaths, one following coronary occlusion, one the result of a pulmonary embolus, and the third occurring in a six-weeks-old infant who had peritonitis at the time of operation. The mortality rate for this group was 0.35 per cent.

The other postoperative complications were 49 in number, an incidence of 5.8 per cent.

Urinary retention.....	11
Wound infection.....	9
Atelectasis.....	8
Pulmonary infarct.....	4
Pneumonia.....	4
Coronary occlusion.....	2
Fecal fistula.....	2
Cystitis.....	2
Swollen testicle.....	2
Phlebitis.....	1
Miscellaneous.....	4
	—
	49

*Follow-up.*—Five hundred and fifty-nine of the 770 patients operated upon for indirect inguinal hernia were examined in the follow-up clinic. Six hundred and sixteen hernia repairs were examined revealing 19 recurrences, an incidence of 3.0 per cent.

*Direct Inguinal Hernia.*—The direct inguinal hernia is seen in the older age-group as the result of an acquired attenuation of the structures which comprise the conjoint tendon. The part played in the development of these herniae by the repeated increase in intra-abdominal pressure during urination and defecation because of obstruction of the bladder outlet or large bowel is now well recognized; and an examination of the lower gastro-intestinal tract and urinary tract should be made before operation on the hernia is undertaken. Two hundred and five patients were operated upon and 279 herniae repaired.

Although these patients were in the older age-group, there were no post-

## SURGICAL TREATMENT OF HERNIAE

operative deaths and only 19 instances of postoperative complications, an incidence of 6.7 per cent. These were:

Wound infection.....	6
Atelectasis.....	3
Swollen testicle.....	3
Hematoma.....	2
Phlebitis.....	2
Pulmonary infarct.....	1
Coronary occlusion.....	1
Influenza.....	1

The type of repair employed was:

Halsted transplantation of cord.....	224
Simple anatomic repair.....	33
Bassini transplantation of cord.....	22
	<hr/> 279

Silk was used as suture material in all except two cases, one which was repaired with cotton, the other with catgut.

The operation was done under local anesthesia in 245 instances, local and general in 3, general in 28, and spinal in 3.

Two hundred and twenty herniae repairs were inspected on follow-up examination. There were 18 recurrences, an incidence of 8.1 per cent.

*Recurrent Inguinal Hernia.*—There were 95 patients who had 103 recurrent inguinal herniae. Twelve of these herniae were of the indirect type and the remainder (91) were direct. The type of repair employed was with few exceptions that of Halsted, with transplantation of the cord to the subcutaneous tissue.

Halsted transplantation of cord.....	88
Bassini transplantation of cord.....	8
MacFee <sup>3</sup> hernioplasty.....	2
Anatomic repair.....	5

All repairs were with silk suture material except one in which catgut was used. Anesthesia employed was local in 93, general in 7, local and general in 1, and spinal in 2.

There were no deaths following operation, but six instances of complications, an incidence of 5.8 per cent.

Wound infection.....	2
Pulmonary infarct.....	1
Atelectasis.....	1
Bronchopneumonia.....	1
Swollen testicle.....	1

Eighty-six patients were examined in the follow-up clinic and 95 herniae inspected of which 14 had recurred, an incidence of 14.7 per cent.

*Femoral Hernia.*—There were 110 patients with femoral hernia in four of whom the condition was bilateral, making a total of 114 herniae. There were 90 women and 20 men in this group. Ninety-three of these patients were over 40 years of age and 53 were over 50. Eighteen patients were admitted to the hospital with acute strangulation of the bowel, which was demonstrated at operation.

The operative procedure was done under local anesthesia in 91, local and general in 3, general in 17 and spinal in 3 cases. Silk was used exclusively for the repair when the operation consisted of the simple anatomic closure of the defect with approximation of the pectineus fascia to Poupart's ligament. In 30 cases a variety of procedures were employed including transperitoneal approach above the inguinal ligament and the method recently described by Moore.<sup>3</sup>

There was one death from peritonitis which was present at the time of operation for acute strangulation of small bowel, a mortality rate of 0.87 per cent. There were seven postoperative complications, an incident of 6.1 per cent which is fairly low considering the age-group.

Phlebitis.....	2
Peritonitis.....	2
Wound infection.....	2
Pulmonary infarct.....	1

Ninety-four hernia sites were examined in the follow-up clinic and eight recurrences found, a recurrence rate of 8.5 per cent.

*Umbilical Hernia.*—Six of 57 patients with umbilical hernia had previously been subjected to operation for this condition. Thirty-one of this group were over 40 years of age and only two were under 18. There were 38 females and 19 males. Fifty-five herniae were repaired with silk and two with catgut. Local anesthesia was used in 35 patients and general in 22. Eight of the herniae were acute on admission to the hospital. Twenty-two were simple anatomic repairs, 19 were operated upon according to the Mayo<sup>5</sup> method and 16 according to the Blake<sup>4</sup> method.

Forty-three patients were examined in the follow-up clinic and five recurrences demonstrated, an incidence of 11.8 per cent.

*Epigastric Hernia.*—Only 12 patients were operated upon for epigastric hernia. These were all located in the midline above the umbilicus and were considered the cause of epigastric pain. Five were multiple, the remainder single. None had been operated upon before. A simple anatomic repair was done with silk in 11 and a modification of a Blake procedure with overlapping of the fascia in one case. Complete relief of epigastric pain was obtained in nine of the 11 patients. There were no deaths and no complications.

Eleven of these patients were reexamined in the follow-up clinic and one recurrence observed, an incidence of 9 per cent.

*Postoperative Ventral Hernia.*—The 136 patients with ventral herniae presented all types varying from small defects following drained appendicectomy wounds to large herniae which contained much of the abdominal contents. Seven were recurrent ventral herniae. Sixteen patients were admitted to the hospital because of acute intestinal obstruction due to strangulation of the bowel. This group may be said to present more difficult surgical problems than all the others in this study since it includes the debilitated, the obese and those who, following previous operations, have had severe and extensive wound infections.

## SURGICAL TREATMENT OF HERNIAE

One hundred and forty-five postoperative ventral herniae in the group of 136 patients were repaired. There were two deaths (mortality 1.4 per cent); one resulted from a pulmonary embolus, the other from peritonitis following operation for an acute hernia. Twelve complications were as follows:

Wound infection.....	4
Atelectasis.....	2
Fecal fistula.....	2
Coronary occlusion.....	1
Pulmonary embolus.....	1
Hematoma of wound.....	1
Peritonitis.....	1

One hundred of these patients were reexamined in the follow-up clinic. There were 12 recurrences, an incidence of 12 per cent.

*Postoperative Complications.*—In the group of 1,385 consecutive patients with 1,545 herniae, 95 patients developed postoperative complications varying in significance, six of which ended in death. There were 13 instances of atelectasis, five of pneumonia and eight of pulmonary infarction. Phlebitis of the lower extremities was noted only 15 times. Coronary occlusion occurred twice and was fatal in one instance. The operative wound was infected in 22 patients, the majority of infections following operation for acute herniae. Seven patients developed peritonitis following operation for intestinal obstruction, a late complication of hernia. In this group fecal fistula was established or developed in four instances. Hematoma requiring revision of the wound occurred in three patients, and swollen testicle in six. Urinary retention, which required an indwelling catheter followed operation for hernia in 11 patients, and a serious cystitis developed or recurred in two women during the postoperative period in the hospital. There were seven miscellaneous complications, such as influenza, measles, otitis media, acute psychosis, etc. The cause of death in six patients was:

Peritonitis.....	3
Pulmonary embolus.....	2
Coronary occlusion.....	1

*Follow-up.*—The late results presented in this paper are based upon observations made in the surgical follow-up clinic six months to three years, or longer, after the patients were discharged from the hospital.

Patients operated upon for hernia are followed at six-month intervals up to three years. About 75 per cent, or 1,037 of the 1,385 patients who compose this group, were examined after operation by a surgeon other than the operator. The incidence of recurrence among the recurrent inguinal herniae as reported by clinics with adequate follow-up facilities ranges from 10 to 30 per cent. Those,<sup>6</sup> using Gallie's method of fascial suture, have not reported better results than those employing silk or cotton. The use of fascial sutures for the repair of inguinal hernia has for the most part been abandoned. The

method advocated by MacFee,<sup>2</sup> in which the cord is transplanted to the femoral canal, offers promise.

*Acute Hernia.*—This term has been employed to designate those patients who require immediate operation because of incarceration or strangulation of bowel. An incarcerated hernia may not necessarily be an emergency but immediate operation to exclude the possibility of strangulation is often indicated because the transition from incarceration to strangulation and intestinal obstruction occurs too frequently to be disregarded.

The recent<sup>7,8</sup> literature reveals that silk is today employed most frequently in the repair of hernia. Cotton suture material is becoming more popular and the use of fine steel wire, as advocated by Babcock, is increasing. As more reports on the experience of early mobilization of patients after operation appear, it is evident that the trend to get patients with repair of indirect inguinal hernia of the congenital type out of bed on the day following operation is justified. However, until longer follow-up studies are available, definite conclusions cannot be stated. The mobilization of the structures in the repair of any hernia and their meticulous approximation without tension by suture material that produces the least reaction, as insisted upon by Halsted<sup>9</sup> in 1893, remains the important principle in this field of surgery.

TABLE I  
SUMMARY OF RESULTS IN 1545 HERNIA OPERATIONS

Type of Hernia	Number of Patients	Number of Operations	Total Patients Followed	Follow-up Results		
				Number of Hernia Repairs Examined	Number of Recurrences	Percentage of Recurrences
Indirect inguinal.....	770	840	559	616	19	3.0
Direct inguinal.....	205	279	144	220	18	8.1
Recurrent inguinal.....	95	103	86	95	14	14.7
Femoral.....	110	114	94	94	8	8.5
Umbilical.....	57	57	43	43	5	11.8
Epigastric.....	12	12	11	11	1	9.0
Postoperative ventral.....	136	140	100	100	12	12.0

#### CONCLUSIONS

1. Fifteen hundred and forty-five herniae treated surgically over a five-year period (1940-1944) are reported.
2. The majority of the postoperative complications are systemic and are of vascular or pulmonary origin. Local complications for the most part are due to infection.
3. Fifty per cent of the deaths and many of the complications occurred in patients who presented themselves for operation with "acute" hernia.

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## SCALENOTOMY

AN ANALYSIS OF ELEVEN CASES DONE FOR SCALENUS ANTICUS SYNDROME

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THE SCALENUS ANTICUS SYNDROME is a term applied to a definite clinical entity that has come into prominence during the last ten to 12 years.

Probably the first reference to the scalenus anticus syndrome was made by John B. Murphy<sup>1</sup> in 1906, who called attention to the rôle of the scalenus anticus in the production of symptoms in patients who also had a cervical rib. Adson and Coffey,<sup>2</sup> in 1927, advocated section of the scalene muscle instead of the removal of the cervical rib in cases where the cervical rib was present, and claimed that it was unnecessary to remove the rib in most cases. In 1935, Ochsner, Gage and DeBailey<sup>3</sup> published a comprehensive study of the subject to which they gave the name "Scalenus Anticus Syndrome," advancing the latter as a definite clinical entity, the symptoms of which are identical with those of cervical rib. They credit Naffziger with being the first to section the scalenus anticus muscle for the relief of symptoms in the absence of a cervical rib. Since 1935, several authors have reported *bona fide* cases of scalenus anticus syndrome which have been benefited by section of the scalenus anticus muscle.

*Etiology.*—A variety of causes for the production of this syndrome have been offered. Adson<sup>2</sup> believed that the symptoms were attributable to two factors: the muscular development of the young adult whose bulging scalene muscles produced the symptoms; and, in older persons, relaxation of the musculature with sagging of the shoulder girdle producing the symptoms. Gage<sup>4</sup> contends that there exists a definite vicious circle that is responsible for the production of symptoms in this clinical entity. This consists of spasm of the scalenus anticus muscle (probably from trauma), which, in turn, elevates the first rib and compresses the brachial plexus, which increases the spasm of the scalenus anticus by reflex action. Todd<sup>5</sup> attributed the predisposition of this symptom complex to faulty development. Normally, during developmental years, the acromial end of the clavicle and the shoulder descend because of the weight of the upper extremity; and the sternal end of the clavicle descends because of contracture of the rectus abdominis muscle which is exerted through the sternum. Either, or both, of a greater than normal descent of the shoulder girdle and a lack of descent of the sternal end of the clavicle may result in compression of the subclavian structures in the scalene angle formed by the first rib and scalenus anticus muscle.

Jones<sup>6</sup> attributes the syndrome to abnormal development of the brachial plexus. In those cases in which the brachial plexus is derived mainly from the cervical segments of the spinal cord, no symptoms occur; whereas, in those

cases in which a considerable portion of the brachial plexus is derived from the thoracic segments, symptoms are likely to develop.

Gage's traumatic vicious circle conception seems to enjoy the greatest popularity.

Haven<sup>7</sup> pointed out that the neurocirculatory symptoms found in the scalenus anticus syndrome may be due to an anomalous formation of the first rib. Roentgenograms in some of his cases revealed an enlarged and short rib which, instead of continuing around to the sternum, formed a synostosis with the second rib at its termination about one-third of reaching the sternum. Relief in these cases was afforded by scalenotomy. Pommerenke and Risteen<sup>8</sup> report four cases of scalenus anticus syndrome as a result of injury to the scalenus anticus muscle due to faulty position of the patient on the operating table. The patient in the Trendelenburg position with the head extended and the arm abducted with the shoulder jammed against braces may sustain injury sufficient to cause symptoms. In two of their cases it was necessary to section the scalene muscle to obtain relief. D'Abreu<sup>9</sup> cites the following: In a tuberculous patient with a fully-formed left cervical rib and an enlarged costal element of the right seventh cervical transverse process to which was attached a fibrous cord, the symptoms of right cervical rib syndrome developed after the upper part of the chest on that side had contracted down during the healing process.

*Clinical Picture.*—The symptoms of scalenus anticus syndrome may be divided into two types: neurologic and vascular.

The neurologic manifestation may originate from both the somatic nervous system and the sympathetic nervous system. Pain may be experienced in the shoulder, arm, forearm, or even extending into the hand. The pain sometimes extends to the cervical spine, to the scapula, and to the thoracic wall. Two of the cases reported in this paper first noticed pain in the breast of the involved side. The character of the pain is variable; it may be of the acute, lancinating type or dull or aching. In some instances the patient experiences remissions and exacerbations alternately. Characteristically, the pain is brought on or aggravated by continuous use of the arm or after repeated movements, such as rotation or extension of the neck. The act of sweeping notoriously causes aggravation of the pain.

Pain can be produced by making pressure over the scalenus anticus muscle; and Gage<sup>4</sup> demonstrated that the pain could be completely relieved by injecting the anterior scalene muscle with one per cent novocaine, which causes a relaxation of the muscle. These patients will seek relief by attempting to keep the shoulder elevated, such as carrying the arm in a sling.

Pressure on the somatic nerves in the scalene angle may produce atrophy of the muscles supplied, most usually of the intrinsic muscles of the hand because the ulnar nerve is most frequently involved. Fibrillary muscular twitching may also be noted.

Sympathetic nervous involvement is manifested by vasomotor spasm, lack of capillary action in the fingers, and reduction of temperature which frequently simulates Raynaud's disease.

Vascular compression is manifested by an obliteration or partial reduction of the pulse volume when the head is turned toward the side of the lesion and a deep inspiration is taken. The blood pressure may be reduced and the pulse may be diminished or absent on the involved side. Ischemia with resultant atrophy may be present. MacFee<sup>10</sup> reports a case in which there was the formation of an aneurysm of the third portion of the subclavian artery distal to the point of constriction, with gangrene of the finger tips. It is noteworthy that nearly all dilatations of the subclavian artery have been distal to the point of constriction. There is no completely satisfactory explanation why the dilatation should occur at this point. Suggestions which have been offered are: Slowing of the blood stream with a resulting increase of lateral pressure; limitation of blood supply to the vessel wall through interference with the vasa vasorum; and trophic changes in the vascular structure due to paralysis of the sympathetic nerve supply. McLaughlin and Popma<sup>11</sup> reported a case of intermittent obstruction of the subclavian vein due to spasm of the anterior scalene muscle. The patient suffered with intermittent swelling and cyanosis of the entire right upper extremity following exertion. Judovich, Bates and Drayton<sup>12</sup> found that compression of the subclavian vein may be caused by spasm of the scalenus anticus causing narrowing of the costoclavicular space or perhaps by pressure on an anomalous subclavian vein passing behind the scalene muscle.

Other findings are inability to elevate the arm above the head, fibrillary twitchings of the various muscles of the upper extremity, fullness of the supraclavicular space, and elevation of the shoulder on the affected side.

Early vascular changes may be elicited by means of the Tycos recording sphygmomanometer. By this method diminished pulse volume may be determined on the involved side.

*Differential Diagnosis.*—Scalenus anticus syndrome is not difficult of diagnosis if the condition is kept in mind. Conditions from which it must be differentiated are: cervical rib, cervicodorsal sympathalgia, Raynaud's disease; subacromial bursitis; supraspinatus tendon rupture; and brachial neuritis. The clinical picture produced by cervical rib is identical with that of scalenus anticus syndrome, their mechanism of production being the same. Occasionally, cervical ribs produce more marked symptoms. Cervical rib can be definitely ruled out by roentgenography. Cervicodorsal sympathalgia may very closely simulate scalenus anticus syndrome because of the nervous and vascular phenomena common to both. The former condition can be definitely eliminated by the complete relief of symptoms following novocaine block of the cervicodorsal sympathetic ganglia. Raynaud's disease is usually bilateral; whereas scalenus anticus syndrome is usually unilateral. The somatic nervous manifestations in Raynaud's disease are absent. In subacromial bursitis and supraspinatus tendon rupture, the tenderness is limited over the supraspinatus tendon and subacromial bursa without other accompanying nervous and vascular manifestations. Atrophy of the deltoid may be a prominent symptom. Abduction of the arm usually increases the pain in cases with subacromial bursitis; whereas this position brings relief in cases of scalenus anticus syndrome. Further, roent-

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genograms frequently show calcification in the region of the tendon and bursa. Brachial neuritis must be considered if local infiltration of 1 per cent novocaine into the scalenus anticus does not bring relief of symptoms.

*Treatment.*—Ochsner<sup>3</sup> feels that conservative methods offer relatively little; and that the only method by which one may obtain complete and permanent relief is by performing scalenotomy. He is of the opinion that the beneficial results by scalenotomy are due to the break in the vicious circle which allows the first rib to assume a lower position, thus, relieving the pressure both on the subclavian artery and the brachial plexus. This is based on the operative observation of the sudden depression and disappearance into the depths of the wound of the first rib following division of the anterior scalene muscle. It is advised that it is desirable not only to divide but also to resect the distal portion of the scalenus anticus muscle because of the possibility of fibrous bridging between the two ends of the divided muscle resulting from organization of exudates.

Hansson<sup>13</sup> observes that several surgeons with extensive experience in the handling of symptoms produced by cervical rib or spasm of the scalenus anticus muscle are agreed that surgical intervention is necessary in only 15 to 20 per cent of the cases. The remainder can be handled by conservative treatment of rest and support, heat to relieve pain and spasm, massage to increase muscular tone and exercise to build up muscular support. He states that postural correction of body mechanics is important and even those who come to surgery should have the benefit of conservative management as a complementary measure. Reichert<sup>14</sup> reports that the majority of patients suffering with this syndrome can be relieved by correcting waking and sleeping posture. Smith<sup>15</sup> presents a case of scalenus anticus syndrome with symptoms simulating coronary disease, without a cervical rib; but with the thickened lateral edge of the cervical fascia posterior and lateral to the scalenus anticus muscle pressing on the third portion of the subclavian artery, resulting in a thrombosis which had become an organized fibrous cord. Division of the fascia where it compressed the artery relieved all of his cardiac symptoms, the pain in his shoulder and arm, and the intermittent claudication while at work as a soda dispenser. He states that there was no evidence, at operation, of compression of the nerves of the brachial trunk.

Patterson<sup>16</sup> believes that, when a cervical rib is present in conjunction with the scalenus anticus syndrome, it is necessary to divide both the anterior and medial scalene muscles and also to resect the cervical rib in order to effect a cure.

In the past, there has been some tendency to include too many disturbances of the upper extremities under the term of "scalenus anticus syndrome," and also a tendency to perform scalenotomy without first determining the exact nature of the symptom complex. For instance, Nachlas<sup>17</sup> doubts that spasm of the anterior scalene muscle is responsible for the production of symptoms. He contends that the scalene angle is actually increased instead of decreased by spasm of the muscle. He further points out that many patients who have



come under his care after having had scalenotomy have shown no improvement. It is his contention that this symptom complex is not primarily caused by spasm of the scalenus anticus, but that the symptoms are associated with lesions of the cervical spine that produce intervertebral foraminal compression of the nerve roots. Falconer<sup>18</sup> describes three cases in which compression of the subclavian vessels with obliteration of the radial pulse was due to compression of the vessels between the clavicle and the first rib. At the time of operation, it was shown that, after section of the muscle, hyperextension of the neck still caused obliteration of the radial pulse, showing that spasm of the scalenus anticus was not the primary factor. Procaine was injected into the muscle to differentiate this mechanism for the production of symptoms from the true scalenus anticus syndrome. The treatment in these cases, with good results, was removal of a portion of the rib and its periosteum to relieve the compression. Semmes and Murphey<sup>19</sup> record that an undetermined number of patients who, heretofore, have been thought to have coronary occlusion, angina pectoris, hypertrophic arthritis of the cervical spine, neuritis of the brachial plexus, bursitis, scalenus anticus syndrome or cervical rib, have, in reality, been suffering with ruptured intervertebral disk of one of the lower cervical vertebrae. Aitken and Lincoln<sup>20</sup> report a case of fractured first rib, a rare condition, which presented all of the symptoms of scalenus anticus syndrome. Relief was obtained by immobilization of the head and neck. Freiberg<sup>21</sup> points out that spasm of the scalenus anticus may be secondary to cervical arthritis or lesions of the shoulder girdle, and that correction of these primary lesions is all that is necessary. Brown<sup>22</sup> reports a case of "winged scapula" as a result of paralysis of the trapezius muscle which followed injury to the spinal accessory nerve. The paralysis of the trapezius caused sufficient sag of the shoulder girdle to place the scalenus on stretch with resultant hypertrophy and spasm, thus, producing the neurocirculatory symptom-complex. Repair of the injury effected a cure. Bishop<sup>23</sup> has shown that calcification of the supraspinatus tendon as a result of repeated minor injuries may cause the scalenus anticus syndrome, the *modus operandi* being reflex spasm of the scalenus anticus muscle.

There are reviewed in this communication 11 consecutive cases of scalenus anticus syndrome for which scalenotomy was done, during the period 1939-1945, at the New Orleans Charity Hospital (Table I).

*Incidence.*—The age-incidence in the 11 cases ranged from 18 to 57 years, with an average of 34 years. The majority occurred in the third decade, which showed four cases. There were nine female and two male patients, of which two were colored females. The left side was involved in seven cases and the right side in four. A relationship between the onset of symptoms and preceding excessive or unusual use of one of the upper extremities was shown in two cases. In one case, the patient became symptomatic after indulging in heavy work; in the other, the patient noticed symptoms after suddenly lifting a baby. The occupations of the others were varied and irrelevant.

*Symptoms.*—The duration of symptoms varied from three weeks to several years with eight of the 11 cases being three months or less. The symptoms

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TABLE I  
ANALYSIS OF ELEVEN CASES OF SCALENUS ANTICUS SYNDROME

Case No.	Age	Sex	Color	Side Involved	Duration of Symptoms	Trauma	Pain + Aching	Total or Partial Disability	Numbness	Muscular Weakness	Muscular Atrophy	Pulse	B.P. Diff.	Reflex Changes	Roentgen Findings	Operation	Result of Operation	Time of Relief	
1	57	M	W	Rt.	4 wks.	O	++	P	Slight	O	O	O	Strong	Same	?	Neg.	Scalenotomy	Excellent	Immed.
2	22	F	C	Left	2 mos.	O	++++	P	O	O	O	r	?	?	?	Unilateral cervical removal of rib	Scal. & Excellent	Immed.	
3	32	F	W	Left	2 mos.	O	++	P	O	O	O	?	?	In-creased	Neg.	Scalenotomy	Excellent	Immed.	
4	28	F	W	Left	2 mos.	O	+	O	Slight	Slight	O	Same	Elev.	Same	Bilateral	Scal. & Poor removal of rib			
5	41	M	W	Left	3 mos.	Heavy work	++	O	Slight	O	O	?	?	?	?	Scalenotomy	Excellent	Immed.	
6	25	F	W	Left	2 mos.	O	+	O	O	O	O	Weak	Elev.	?	?	Bilateral cervical	Excellent	Immed.	
7	18	F	W	Left	3 mos.	O	++	O	O	O	O	?	?	?	?	Scalenotomy	Excellent	Immed.	
8	41	F	W	Rt.	3 wks.	Lifting baby	++	O	O	O	O	Weak	Same	?	Neg.	Scalenotomy	Excellent	Immed.	
9	23	F	W	Rt.	4 yrs.	O	+	O	O	O	O	?	Same	?	?	Unilateral cervical	Good	Immed.	
10	34	F	W	Rt.	Several years	O	+	O	Slight	O	O	O	Same	?	?	Scalenotomy	Excellent	Immed.	
11	54	F	C	Left	7 mos.	O	++	P	Slight	Slight	O	?	?	?	Neg.	Scalenotomy	Excellent	Immed.	

were variable; and, except for the more prominent objective signs in those cases having cervical ribs, were, in general, essentially the same. The most consistent symptom was pain ranging from the dull, aching type to the sharp, lancinating type. Numbness was recorded in five cases and muscular weakness in two cases. No cases were recorded as having muscular atrophy. In the majority of cases, the location of pain was the side of the neck, shoulder, and upper arm. Two of the female patients first noticed pain over the breast on the involved side.

*Reflex Changes.*—Reflex changes were not recorded in nine of the cases. In the two remaining, no change was noted in one and in the other the reflexes of the extremity were hyperactive.

*Vascular Changes.*—Of the six cases in which blood pressure readings were recorded in both arms, one showed a slight elevation on the involved side; one, a slight decrease on the affected side; and the remaining four showed no difference between the two recordings. The differential pulse recordings were as follows: stronger on the involved side in one case; weaker on the involved side in two cases; and the same in both extremities in two cases. In the remaining cases, the differential pulse was not recorded.

*Roentgenologic Examination.*—Bilateral cervical ribs were demonstrated in two cases. Both of these cases presented symptoms on the left side. Unilateral cervical rib was demonstrated in two cases. In both of these cases, symptoms were present on the ipsilateral side, one presenting symptoms on the left and one on the right. It should be emphasized that cervical ribs, when bilateral, are not easy to diagnose unless one is on the alert for the anomaly.

*Operative Procedure.*—The operative technic in all of the cases was essentially the same as that described by Ochsner, *et al.*<sup>3</sup> Scalenotomy alone was done in nine of the cases. Resection of the cervical rib in addition to the scalenotomy was done in one case of unilateral cervical rib; and in one case of bilateral cervical rib, a portion of the rib was removed in addition to the scalenotomy on the affected side. Bilateral scalenotomy was done in none of these cases. Spurling and Bradford<sup>24</sup> call attention to the temporary paralysis of the diaphragm in these cases following traction on the phrenic nerve and advise against bilateral tenotomy of the muscle in one stage. Donald and Morton<sup>25</sup> and others, however, have performed bilateral scalenotomy at one sitting, without any ill effects.

*Operative Results.*—All but one of these cases obtained complete relief of symptoms immediately following operation. The longest follow-up period, according to the records, was approximately one year. The one case of bilateral cervical ribs in which the result was poor was still complaining of pain two months following operation.

#### SUMMARY AND CONCLUSIONS

(1) The scalenus anticus syndrome, in general, is discussed, and 11 cases presenting symptoms of this entity are reviewed.

(2) Seven cases were not associated with a cervical or abnormal rib,

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indicating that the scalenus anticus syndrome occurs with much greater frequency than the cervical rib syndrome.

(3) The symptoms are the result of spasm of the scalenus anticus muscle, resulting in compression of the brachial plexus and subclavian artery, with the creation of a vicious circle.

(4) Attention is called to the fact that many cases of scalenus anticus syndrome may, in reality, be secondary to some other underlying primary pathology.

(5) Scalentomy may not be necessary in mild cases, conservatism being all that is necessary to bring about permanent relief.

(6) The results following scalentomy in the series reported here have been excellent, only one case of bilateral cervical ribs failing to respond to treatment.

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## EXPERIENCES WITH POSTTRAUMATIC OSTEOMYELITIS IN WORLD WAR II

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OUR PURPOSE in presenting this material is to evaluate, insofar as is possible, our results in the treatment of osteomyelitis in Chinese battle casualties of the North Burma Campaign of 1943-1945. This is an elaboration and continuation of a report already published by Weeden and Stein.<sup>1</sup> Two factors must be first made clear: (1) Definition of osteomyelitis. (2) Method of interpreting end-results.

Chronic infection of the bone resulting from infected compound fractures as a result of trauma is not justly comparable to hemogenous osteomyelitis. The process is far less fulminating and its management proceeds along entirely different lines. Data for practical reporting or statistical analysis was collected from those case histories in which positive statements were recorded; *i.e.*, a roentgenologic diagnosis of osteomyelitis; a report by our pathologist on the nature of the operative specimens; or, a note by the operating surgeon that osteomyelitis or a sequestrum, or both, were encountered. Patients were managed by all of the surgeons in the hospital, and not segregated. Frequent observation and consultation by the Chief of the Surgical Service, however, tended to effect greater uniformity than this description suggests.

An accurate comparison of the results of treatment of the chronic osteomyelitis encountered in World Wars I and II is not intended. The supplementary use of the sulfonamides has encouraged present-day surgeons to attempt primary closures, and, in the opinion of many surgeons, has completely altered the management of the disease, from that encountered in the military hospitals during World War I.

Caldwell<sup>2</sup> has concluded that the pre- and postoperative use of sulfonamides is indicated when reconstruction of infected fractures is anticipated, because it reduces systemic and local diffusion of infection. However, elimination of local bone infection should not be anticipated. Our impressions justify this conclusion. Yet Dickson, Dendey and Kiene<sup>3</sup> reported a series of 22 patients in whom the osteomyelitis was treated by pre- and postoperative sulfathiazole, saucerization, wound closure, and immobilization, with complete healing occurring in 82 per cent of instances on an average of 23 days. Badgley and Harris<sup>4</sup> described a series of 25 case histories of old nonunited, infected fractures. In the presence of infection definite reconstructive procedures were performed. Wounds were left open, and 72 per cent of cases united and were healed on an average of 13 months. The

obvious difference in the healing period brings up the whole question of whether such wounds may be closed safely, now that the sulfonamides are available.

In 1944, Key<sup>5</sup> began the treatment (over a 2.5-year period) of 101 consecutive cases of osteomyelitis, administering sulfathiazole for five days pre- and 15 days postoperatively. The tibia was involved in 33 instances, the femur in 24, and other bones in 44. Including 11 amputations, 60, or 59.4 per cent, healed *per primam*. The reports are not classified as to the percentage of healing occurring in each bone studied, and the inclusion of amputations seems unwarranted.

Tourney<sup>6</sup> reported the cases of 13 patients very similarly managed, with healing in ten instances, or 76.8 per cent. The series is small, and a comparison of healing in upper and lower extremity lesions is, again, not reported.

That chronic infection, associated with retained sequestra or foreign bodies, is often sulfa-resistant, and that the debilitated status of many patients may contraindicate sulfonamide therapy was well-recognized by Lyons.<sup>7</sup> Both Speed<sup>8</sup> and Baker<sup>9</sup> concluded that the local use of sulfonamide is of help in combating infection, only when the fundamental rules of wound hygiene have been followed. Baker rightly asks what results might be obtained from adequate surgery without chemotherapy, because of the relative lack of improvement from the addition of sulfonamide to the open method. After a study of data gathered from the case histories of 2,191 patients, 674 compound fractures, Meleney<sup>10</sup> came to a conclusion somewhat similar to that of Speed and Baker.

In these patients the chief factors concerned with the development of infection were found to be as follows:

1. The degree and extent of tissue damage.
2. The degree of gross contamination by dirt and other foreign bodies.
3. Time-interval between injury and initiation of surgical care.
4. The nature of the bacterial contamination of the wound.
5. The care and thoroughness with which the devitalized tissue, foreign bodies and gross contamination were removed from the wound.

Meleney<sup>10</sup> could not demonstrate that sulfonamides, locally or systemically, materially reduced the incidence or severity of local infections, or eliminated the pathogenic organisms from the wounds. Spread of local infection was minimized, however, and hence the incidence of septicemia and death decreased, when the drug was administered by systemic means.

The bulk of the evidence, therefore, seems to force us to conclude that the addition of the sulfonamides to our armamentarium in the treatment of chronic osteomyelitis has had its greatest value when employed systemically, and acts in the following manner:

1. The disease remains as a localized process in the bone involved, instead of producing a fulminating and disseminating process.

# POSTTRAUMATIC OSTEOMYELITIS

2. Preoperative sulfonamide therapy will frequently decrease the infection of the adjacent soft tissues, and sometimes clear it up entirely.

Improvement and standardization of sound surgical principles are still of the greatest importance in the management of the local infection of soft tissues and bone.

The material upon which this report is based consisted of 365 Chinese soldiers, almost all of whom fought in the Hukawng and Mogaung Valleys, and between Myitkyina and Bhamo along the Irawaddy River in the North Burma campaign of 1943-1945. Whereas, they are a sturdy race, many of the soldiers were afflicted with chronic malnutrition, malaria, dysentery and venereal diseases. The recurrence of malaria after any operative procedure was quite frequent, and it is hard to believe that chronic diseases did not have some deleterious effect on wound healing.

TABLE I  
RESULTS

Bones	Total	Per Cent	Healed at 3 Months	Per Cent	Hosp. Av.	Full Duty	Per Cent	Limited Duty	Per Cent	Disab. Duty	Per Cent
Tibia.....	76	20.7	36	47.3	10.3	46	60.5	14	18.4	16	21.0
Femur.....	64	17.7	17	26.5	7.2	35	54.6	5	7.9	24	37.5
Humerus.....	50	13.6	21	42.0	6.4	27	54.0	11	22.0	12	24.0
Ulna.....	28	7.6	14	50.0	5.5	18	64.3	8	28.5	2	7.1
Radius.....	26	7.1	16	61.5	8.8	16	61.5	5	19.2	5	19.2
Phalanges.....	23	6.3	12	52.2	3.8	18	78.2	3	13.0	2	8.7
Metatarsals...	22	6.0	7	31.8	5.5	10	45.5	4	18.1	8	36.2
Pelvis.....	14	3.8	6	42.8	5.9	11	78.6			3	21.3
Ribs.....	13	3.5	7	53.9	5.1	10	76.9	1	7.7	2	15.4
Metacarpals..	12	3.3	9	75.0	4.5	11	91.6			1	8.3
Fibula.....	12	3.3	7	58.3	5.9	7	58.3			5	41.6
Oscalcis.....	9	2.5	2	22.2	6.7	8	88.8			1	11.1
Scapula.....	8	2.2	4	50.0	3.8	5	62.5	2	25.0	1	12.5
Sternum.....	4	1.1	2	50.0	5.5	3	75.0			1	25.0
Carpals.....	4	1.1	3	75.0	8.3	3	75.0			1	25.0
Clavicle.....	3	0.8	2	66.7	6.0	2	66.6			1	33.3
Total.....	368	100.0	165	44.8	6.2	230	62.6	53	14.5	85	23.0

The diagnosis of osteomyelitis, as we have defined it elsewhere, was established in every instance by radiographic means, the presence of infected bone and marrow, or the removal of a sequestrum. Whereas, it might theoretically be advisable to divide our study into that of frank osteomyelitis and sequestration, for practical purposes the same disease exists in both instances. Hence, no attempt will be made to differentiate between the end-results of each, since the extrusion or removal of a single sequestrum by no means guarantees cure.

Although such information was not always found on the accompanying slips or charts, we presumed that all cases received débridement and encasement in the Portable Surgical Hospitals and Aid Stations in the Forward Area. Many of them must have been given a variable amount of one of the sulfonamides.

Osteomyelitis of the skull, jaws and vertebrae is not included in this study.

*Analysis.*—It is readily seen that the tibia is by far most commonly injured and involved by infection. Likewise, the healing period (10.3 months) from injury to discharge on duty status is considerably longer than that of the humerus (6.4 months), or femur (7.2 months). This is probably due to its subcutaneous position and often inadequate and compromised blood supply.

The bones of the forearm, particularly the radius, are seen to respond fairly well to surgery.

## REOPERATIONS REQUIRED

Radius.....	3.8%
Ulna.....	7.1%
Femur.....	18.7%
Tibia.....	26.3%
Humerus.....	16.0%

Here, again, the necessity for reoperations is seen to be far higher in the case of the lower extremity than in the upper.

*Primary Closure.*—When adequate soft tissue was available the closed method was applied to those cases. This type of wound management was employed in 69 instances. Patients were routinely given sulfonamide gr. 15

TABLE II  
RESULTS OF PRIMARY CLOSURES OF WOUNDS

Bone	No.	SUCCESSSES		Secondary		Total		Failures	
		Healed	Prim.						
Femur.....	9	2	22.2%	4	44.4%	4	66.6%	3	33.3%
Tibia.....	16	9	56.2%	3	18.3%	12	74.5%	4	25.0%
Humerus.....	12	8	66.6%	2	16.6%	10	83.4%	2	16.6%
Radius.....	9	5	55.5%	3	33.3%	8	88.8%	1	7.5%
Ulna.....	9	2	22.2%	4	44.4%	6	66.6%	3	33.3%
Scapula.....	2	2	100.0%			2	100.0%	0	0.0%
Phalanges.....	4	3	75.0%			3	75.0%	1	25.0%
Carpal.....	3	3	100.0%			3	100.0%		
Metacarpal.....	2	2	100.0%						
Pelvis.....	3	2	66.6%	1	33.3%	3	100.0%		
Total.....	69	38	55.2%	17	24.6%	55	79.8%	14	20.3%

four times daily for three to four preoperative and about seven to fifteen postoperative days. Plaster encasement was applied in all instances. A definite attempt was made to remove all infected tissue both soft and osseous. Wherever possible adjacent muscles were approximated closely to the defect and a pressure dressing applied. Our results in the case of these 69 patients were as follows:

Primary healing.....	38	55.2%
Secondary healing.....	17	24.6%
	55	79.8%
Failures.....	14	20.3%

The results of employment of primary closure was thus satisfactory in 79.8 per cent of patients so treated. As regards wound healing (Table II) the total length of hospitalization before return to duty status was not

# POSTTRAUMATIC OSTEOMYELITIS

appreciably shortened (Table III), except in the case of those patients in whom the ulna alone was involved. The most significant advantage of the closed method lies in the fact that a definitely larger percentage of patients was returned to full duty (Table IV) when the femur, tibia or humerus were involved by osteomyelitis. Wounds of the forearm were complicated by injuries to numerous important adjacent structures to such an extent that a return to duty status was less frequently possible (Table V):

Three patients (0.82 per cent) died subsequent to operative treatment. One of these had far-advanced (Grade IV) pulmonary tuberculosis. His death occurred 12 days after total scapulectomy, at which time the operative

TABLE III  
COMPARISON OF HOSPITALISATION  
PRIMARY CLOSURES AND OPEN CASES

Bone	Primary	Open
Femur.....	7.2 months	7.5 months
Tibia.....	6.5 months	6.6 months
Humerus.....	5.2 months	5.7 months
Radius.....	8.2 months	7.8 months
Ulna.....	5.0 months	7.4 months

TABLE IV  
COMPARISON OF FULL DUTY STATUS  
PRIMARY AND SECONDARY METHODS

Bone	Total Cases	Cases to Duty	Closures (Primary)	Closures to Duty	% to Duty	Total Open	Open to Duty	% Open to Duty
Femur.....	64	35	9	8	88.8	55	27	49.0
Tibia.....	76	46	16	7	43.7	60	39	65.0
Humerus.....	50	27	12	7	58.3	38	20	52.6
Ulna.....	28	18	9	5	55.5	19	13	68.4
Radius.....	26	16	9	3	33.3	17	13	76.4

wound was clean. The two remaining deaths occurred in patients who had extensive osteomyelitis of the ribs. In each case the original trauma had involved intrathoracic organs, and the patients died of intrapleural infection.

## OPERATIVE MANAGEMENT

1. Because of extensive hemorrhage, whenever possible, a tourniquet was applied well proximal to the operative site, and extremely hot packs were available. Upon only a few occasions were pressure packs left in the wounds, and these were removed in two to three days.

2. Whenever curettage of the femur was contemplated, infusions of glucose or saline were started. Plasma was always available, but so great was the shock at times that transfusions of whole blood rapidly forced into the femoral vein were required. We are certain that this form of management prevented many accidents which might have cost the patient his life.

3. Strict adherence to the Orr-Trueta principle, as practised in the Forward Area, is not recommended in the Rear Echelon. Long periods of



immobilization often result in poor circulation of blood and lymph, skin damage, muscle atrophy and stiffness of joints. Wherever there was no danger of pathologic fracture, the plaster encasement was removed three weeks, postoperatively, and the wound treated by infrequent dressings. Earlier return of function resulted from this form of management.

Physiotherapy was often relatively ineffective as the individual soldier, because of pain, could not be convinced of the necessity of doing anything for himself in the way of active motion. As a consequence, many of the Chinese patients will not obtain the functional result expected in American patients.

TABLE V  
COMPLICATIONS

Bone	Nerve Lesion	Soft Tissue Lesion	Tendon Lesion	Muscle Lesion	Bone Graft	Poor Function	Painful Gait	Painful Scar	Ankylosis	Deformity	Others
Femur.....							2	2	Ankle 6 Knee 1		Nonunion 1 Hysteria 1 Hysteria 1
Tibia.....	Perineal 2				2	4		8	9		
Fibula.....			1			3			1		
Metatarsals.....		2							2	2	Causalgia 1
Os calcis.....							4	1			
Pelvic bones.....							1				Pyarthrosis 1
Scapula.....						1		1			TBC.
Clavicle.....											Causalgia 1
Sternum.....											Pyarthrosis 1
Humerus.....	Radial 9 Median 1			3	3				9		Causalgia 2 TBC. 1
Radius.....	2	1	3		5				1		
Ulna.....	2	1	2		3				1		Cross-union 1 Lues 1
Carpals.....	1		3								
Metatarsals.....		1						3	1		
Phalanges.....		1			1	2			1		
Ribs.....											Pleural comp. and death (TBC.) 2

#### SUMMARY

1. A report of 368 cases of osteomyelitis in Chinese soldiers is herein summarized.

2. The tibia is most frequently involved, followed by the femur and ulna.

3. Radical débridement of diseased soft and osseous tissue and good surgical toilet is imperative if a definitive arresting of the disease is to be attained.

4. Employment of sulfonamides systemically probably results in a more localized pathologic process, and, certainly, prevents dissemination of the disease. The rationale of local use of sulfonamides is doubted.

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5. Primary closure is recommended in the management of osteomyelitis when adequate soft tissue is available. Otherwise, the open method is advocated.

6. Early removal of the plaster encasement is recommended where pathologic fracture is not apt to follow such management, to permit earlier recovery of skin, soft tissues, circulation and joints.

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## BONE GRAFTING METHODS

### TWO ILLUSTRATIVE CASE REPORTS

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EVOLUTION OF BONE GRAFTING during the past 100 years is a fascinating story. The bitter controversy that waged about the monumental work of Macewen and Ollier regarding the rôle that periosteum plays is still not completely settled. It is interesting to note that the 3-year-old child upon whom Macewen illustrated his most striking experiment in the problem of bone grafting was done by packing chips of bone into the sleeve of the periosteum which remained after the humeral shaft had been excised because of a long-standing osteomyelitis. At present, the common method of grafting consists in using either the intermedullary, inlay or the various types of onlay graft. We are only beginning now to appreciate the tremendous value of utilizing bone chips and masses of cancellous bone packed about the graft.

In all bone grafting operations the following are desired: First, excision of avascular scar tissue as far as is consistent with good surgery, and this includes both osseous and soft-tissue and the use, sometimes, of preliminary skin grafting; second, operation in as clean a field as possible; third, immobilization by firm fixation of the graft to the proximal and distal bone to be bridged; fourth, adequate support and splinting which should be continued during the restoration of function of the part; and fifth, roentgenologic evidence of solid bony union.

The "massive" bone graft term was apparently first popularized by Henderson, and the principle has been employed in the two cases herein reported. The bridging of the large defects can be accomplished by the use of the split-graft or the whole-graft. In the two cases herein reported each method is demonstrated.

### CASE REPORTS

**Case 1.**—Mrs. S., age 30, gave a history of having injured her right knee in December, 1931 and February, 1932, followed by swelling and pain. On March 19, 1932, she was operated upon. A giant cell tumor of the lower end of the right femur was found, and verified by pathologic report. From March, 1932 until February, 1945, the patient had a number of different treatments to the knee. During the 13-year period the wound had never healed, and she has received radiation implantation into the wound, seven currettages and a long course of roentgenotherapy. She presented chronic suppurative osteomyelitis, with a large, draining, foul-smelling sinus in the region of the external condyle of the femur. Culture revealed *hemolytic Streptococcus* and *Staphylo-*

\* Cases presented at Joint Meeting of the New York Surgical Society and Philadelphia Academy of Surgery, College of Physicians, Philadelphia, February 13, 1946.

## BONE GRAFTING METHODS



FIG. 1.—Case 1: On admission to the University Hospital, showing extensive chronic osteomyelitis before resection. Gross specimen showed no evidence of previous giant cell tumor but necrotic shell of bone.

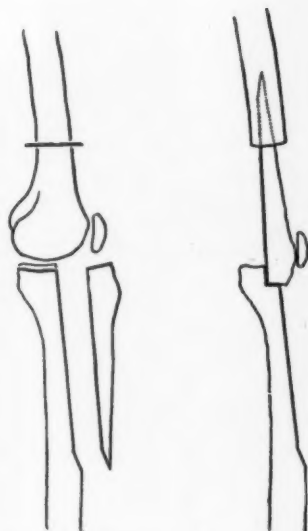


FIG. 2.—Showing diagram of steps of operation.



FIG. 3.—Showing massive tibial bone graft in place after removal of transfixion pins put in at time operation.



FIG. 4.—Showing bony union, proximally and distally, of tibial graft one year after operation. Note increase in growth of graft and callus formation.

*coccus albus*. She retained about 10° motion in the knee and walked with crutches, complaining of pain constantly.

On February 20, 1945, she was admitted to the Orthopedic Service at the University of Pennsylvania Hospital, and, on February 28, 1945, a resection of the distal 13 centimeters of the femur was done. A massive tibial graft was removed from the tibia, and placed in position shown in diagram. Technically, the operation was not difficult and was done under tourniquet. The knee joint was approached by a medial patellar incision after carefully blocking the cavity with sterile dressings and incising the skin about the periphery of the sinus, sealing-off as far as possible the infected draining area. After opening the knee joint, a midline incision was then made over the anterior surface of the femur through the vastus intermedius muscle, exposing the shaft of the femur. The entire cortex of the femur up to the site of anticipated division was exposed by stripping the muscles subperiosteally. A Gigli saw was gently introduced around the bone and this was divided 13 centimeters above the knee joint. The entire distal portion of the femur was then shelled out of its bed and separated from its muscular and ligamentous attachments. The cartilage from the upper articular surface of the tibia was removed and a large, long graft consisting of approximately half the thickness of the



FIG. 5-A

5-B

FIG. 5-A.—Present brace patient is wearing (front view).  
5-B.—Present brace patient is wearing (back view).



# BONE GRAFTING METHODS



FIG. 6.—Case 2: On admission to University Hospital after four unsuccessful attempts to obtain bony union. Note useless position of hand with prominence of ulna styloid.

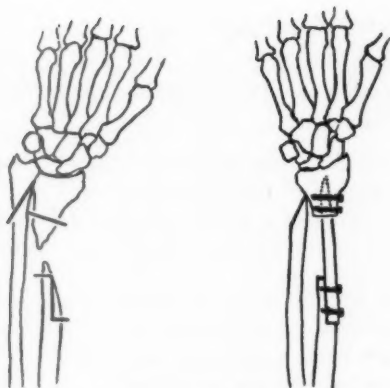


FIG. 7.—Showing diagram of steps of operation using whole-thickness fibula graft.



FIG. 8.—Showing graft in position held with four vitallium screws.

tibia removed and turned upward, inserting the distal end of the graft into the intramedullary cavity of the femur and the opposite end in the prepared bed in the tibia. The graft was held in position by Steinman pins which protruded through the skin and were later incorporated in the plaster. The wounds were then closed in layers, both the anterior and lateral wounds and a plaster spica applied. The pins remained in for six weeks and were removed when the plaster was changed. About seven months after the massive bone graft operation a walking-iron was fitted into the spica and the patient allowed to bear weight. Ten months after operation all plaster



FIG. 9



FIG. 10

FIG. 9.—One and one-half years postoperatively, showing site of removal of fibula graft. No disability whatsoever.

FIG. 10.—One and one-half years after whole-thickness fibula graft and Darrach operation upon ulna; resulting in normal rotation and good symmetry to the wrist.

was removed and she was fitted with a pelvic ring, long leather cuff-type of brace, as shown in diagram. Roentgenograms before and after operation are shown.

The patient is now walking about with the aid of a brace and apparently has solid bony union at the proximal and distal portion of the graft, as shown in Figure 9, approximately one year after operation.

**Case 2.**—R. A., female, age 49, gave a history of having fallen, May, 1942, and fractured her left radius and ulna styloid process. The fracture was treated by her physician, and on removal of plaster six weeks later, a nonunion was noted. Following this she had three attempts at obtaining union by open operation, without success.

When she was first seen by the writer, December 16, 1943, she presented the picture as shown in Figure 1. The hand was markedly deviated, the ulna was very prominent and frank nonunion was noted. Marked thickness of the wrist, loss of function in the fingers of the hand, and complete loss of pronation and supination were noted. On July 11, 1944, she was admitted to the Orthopedic Service, at the University of Pennsylvania Hospital, and, July 12, 1944, a whole-thickness fibula graft

## BONE GRAFTING METHODS

was used. It was decided to use this type of graft in order to preserve a complete cortical surface, believing that a freer gliding motion of the tendons could thereby be expected.

The operation was as follows: Under a blood pressure cuff the Darrach operation was first done, excising the distal portion of the ulna. Another incision was made over the radial aspect and the sclerotic ends of bone at the site of nonunion along with the wire that had been placed there in a previous operation were removed. All scar tissue of the soft-part had to be totally excised. When this was completed there was a gap of about two and one-half inches between the radial ends, and when traction was made on the hand to correct the radial deviation, a good three inches remained to be bridged. The middle third of the fibula on the same side was then removed subperiosteally. The graft was driven into the distal fragment and attached to the proximal fragment, as shown in the diagram, and held in place by four vitallium screws. Plaster was applied from the fingers to the middle of the arm, with the elbow at a right angle and the hand in slight ulnar deviation. The wound healed *per primam* and subsequent roentgenograms showed continued evidence of solid bony union. Three months after the operation all support was removed. On January 11, 1945, she was admitted to the hospital for removal of the screws and, as shown by roentgenograms, she had solid bony union. A roentgenogram of the defect in the fibula caused by the removal of the graft is shown. This is not giving her any trouble and has not resulted in any disability whatsoever. At present, one and one-half years after the operation, she has a practically normal range of rotation and finger motion, with very slight limitation in the movements of the wrist.

## EXPERIMENTAL OBSERVATIONS ON ABSORBABLE ALGINATE PRODUCTS IN SURGERY\*

GEL, FILM, GAUZE AND FOAM

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LATE OF THE BIOLOGIC RESEARCH STAFF POOL, WAR OFFICE

IMPORTANT ADVANCES have been made in the prevention of adhesion formation in the course of tissue repair, the arrest of capillary hemorrhage and the closed treatment of burns during the war years through the development of new materials.

Fibrinogen products from plasma in the form of film, foam, and with the aid of thrombin, into clot, were prepared by the various Departments at Harvard University.<sup>1, 2</sup> As a film, it is stated to fulfill the requirements of an absorbable tissue isolator,<sup>3</sup> keeping injured tissues apart in course of their healing; applied as foam or solution to an oozing surface, combined with either added or locally produced thrombin it arrests hemorrhage,<sup>3</sup> and painted or sprayed in a glycerol plasticized solution on a wound or burn it gives a flexible, impermeable cover.<sup>2</sup>

Cellulose compounds and polyvinyl plastics were used in experiments by Frantz,<sup>4</sup> at Columbia University, New York. The grades of polyvinyls used proved too irritable to tissue and nonabsorbable; oxidised cellulose (oxycellulose), however, was stated to be useful. It sets up a minimal fibrous tissue reaction and becomes absorbed in tissue.<sup>4</sup> Putnam<sup>5</sup> made use of this soluble cellulose, combined with thrombin, in neurosurgical operations, and reported satisfactory results; other satisfactory results were reported by Frantz and Lattes,<sup>6</sup> who submitted oxycellulose gauze to clinical trial for the arrest of capillary hemorrhage.

Casein films formed *in situ*, methyl cellulose, and polyvinyl chloride films were recommended by others for the treatment of extensive burns.<sup>7</sup>

None of these materials are free from disadvantages. Fibrinogen and oxycellulose are not sterilizable by current methods, using heat and pressure; their sterilisation is by the formalin method and, consequently, bacteriologic control is necessary. Oxycellulose was found to be incompatible with penicillin. Casein films in burns need an additional impermeable cover. Polyvinyl chloride and methyl cellulose film are nonabsorbable, and their use is, thus, restricted to external application.

The introduction and description of a new material for these purposes can be warranted only if it shows conspicuous advantages over those used at present. It must be absorbable at a readily controllable rate. The tissue reaction caused by it must compare favorably with protein films and with oxycellulose.

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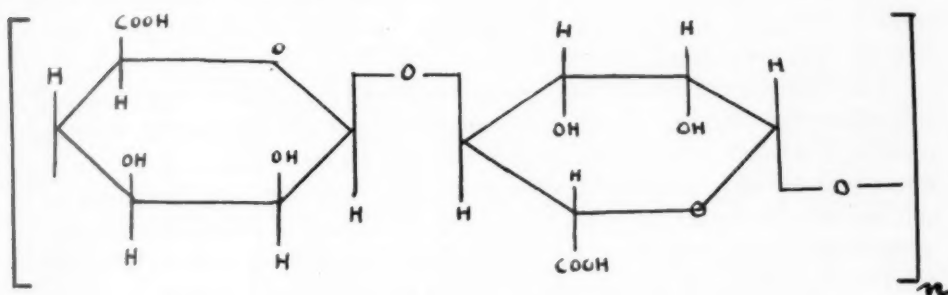
Mr. C. W. Bonniksen, Chief Chemist of Alginate Industries Limited, Maidenhead, Berkshire, England, is to be thanked for samples of alginates and all technical information.

## ALGINATE PRODUCTS IN SURGERY

It should be easier and cheaper to produce than, say, fibrinogen plastics. It must be compatible with penicillin and other antibacterial substances. It must allow sterilization by current routine methods. Its physical properties must allow modification of plasticity. Finally, it ought to be able to "carry" substances ensuring their controlled, delayed absorption in the organism.

Such an ubiquitous material has been found in the extract of the brown seaweeds. This extract—alginic acid—is yielded alone on hydrolysis of this type of seaweed.

Alginic acid is a polymer of d-mannuronic acid. It was discovered by Stanford,<sup>8-9</sup> in 1882, in course of kelp extraction experiments in Scotland. Its formula bears a striking resemblance to that of cellulose, with the difference that the alcoholic group is here replaced by the carboxyl group ( $C_6H_{10}O_7$ ). By the control of the rate of hydrolysis a wide viscosity range is possible, viz. from Grade 6 to Grade 1,000, representing a mean molar mass of 25,000 to 200,000.



Photograph showing the molecular structure of alginic acid.

Many salts can be prepared from alginic acid. The acid itself is not soluble in water; some of the organic bases and the salts of the alkali metals are. The other inorganic bases are insoluble.

The sodium salt of this acid, sodium alginate ( $NaAlg$ ), when acted upon by ionic calcium, undergoes instantaneous coagulation. This reaction is the basis of preparing clot, film, filament (from which gauze can be woven) or foam. A certain limited range of "rigid" plastics objects can also be prepared with some modification of technic.

The reaction which takes place is according to the formula— $2NaAlg + CaCl_2 \longrightarrow CaAlg_2 + 2NaCl$ —which reaction is reversible, *in vitro*, by double decomposition, thus,  $CaAlg_2 + Na_2CO_3 \longrightarrow 2NaAlg + CaCO_3$ .

Sodium alginate is supplied as a granular or fibrous powder in various Grades. When stirred into water it tends to lump and a high speed stirrer is, therefore, useful in the preparation of the solution. Owing to enzymic decomposition, if left standing at high atmospheric humidities, and the danger of bacterial growth, solutions to be kept for any period should have 0.1% phenol or formaldehyde added. If it is desired to "time" the reaction, a suspension of calcium sulphate is used which coagulates sodium alginate slower than calcium chloride. The incorporation of calgon (sodium hexametaphosphate) controls the reaction. At an acid  $pH$  coagulation is quicker than at an alkaline  $pH$ .



The moisture-holding capacity of alginates is high, of the order of 18-20%. The salts are relatively stable at ordinary temperatures, and humidities, but when wetted, they become subject to attack by certain moulds and enzymes.

Although salts of metals other than of calcium can be used to coagulate alginates, calcium alginate has so far been found to be most useful, as its degree of contraction on drying is lowest; it has excellent film-forming properties; filaments of calcium alginate can be easily prepared by extruding a viscous solution of sodium alginate through jets passing through a bath of coagulant, such as calcium chloride.

Calcium alginate will absorb its own weight of water or even more, under favorable conditions. Other salts like zinc, aluminum, chromium and beryllium alginates are less susceptible to swelling.

The faculty of coagulation of sodium alginate by calcium salts is very sensitive. The reaction takes place with solutions of sodium alginate of the order of 0.1 per cent and of calcium chloride of 0.1 per cent, the higher the molecular weight and concentration of sodium alginate and the higher the percentage of the calcium salt used, the firmer and tougher clot, or film, or filament is obtained. It must be borne in mind, however, that solutions of over five per cent are unworkable.

The sensitivity of the clotting mechanism of sodium alginate with a calcium salt allows the "mixing in" of a high proportion of other solutions, such as plasma. Coagulation was obtained with 90 parts plasma added to ten parts of five per cent sodium alginate solution, reacted upon by concentrations of calcium chloride from 0.5 per cent upwards, or by using a tenth-molar solution of calcium glycerophosphate. The reaction can, therefore, be used as a clotting reaction for plasma. Filaments containing up to 20 per cent plasma or 20 per cent casein were also prepared. These were of a higher tensile strength, but of a lower wet strength and knotting strength, than calcium alginate filaments.

**Physical Properties of Alginate Gel, Film, Gauze and Foam:** (A) *Gel*: When sodium alginate and calcium chloride are reacted to form a clot, this clot is soft, pliable and, on squeezing, excess calcium can be expressed. If allowed to dry, the clot contracts to a very small size and becomes pearly hard in 48 hours at room temperature at a low humidity of the air. Thus, for instance, if a big drop of sodium alginate is carefully dropped into a pool of calcium chloride, a spherical "pearl" of calcium alginate forms at once, with a mean diameter of approx. 1-2 mm. If this sphere is now exposed to drying at room temperature at a low moisture grade, in 48 hours it contracts to the size of a pinhead, with a mean diameter of approximately 0.1 mm. In this stage it can be sprayed similar to salt, through the openings of a rather coarse salt container. Placed in water, it will regain its former size in about 48 hours. In spite of its hardness it becomes absorbable in the organism.

(B) *Film*: Calcium alginate film can be prepared in any thickness. A film, say, 10-30 mu. in thickness, when dry, is tough, somewhat brittle, but with a fair degree of tensile strength. Placed in water it is made pliable. The addition of plasticisers, *e.g.*, glycerol, yields an absorbable film which is already plastic in its dry state exhibiting none of the brittleness of dried calcium alginate. On the whole, the films are not unlike various grades of cellophane with which they share absolute transparency.

(C) *Filaments*: Filament yarns of two varieties can be prepared, namely; monofilaments and polyfilaments. In the former, extrusion takes place through a comparatively large-sized "spinnerette," and the filament thus obtained is made of one fiber. In the latter, a number of very thin filaments are extruded and twisted upon one another to form composite fibers of up to 200 individual fibers.

## ALGINATE PRODUCTS IN SURGERY

The tensile strength of the filaments is of the same order as viscose. The great reduction of strength on wetting renders calcium alginate filaments unsuitable as a surgical suture.

(D) *Gauze*: Gauze is woven from calcium alginate polyfilaments. The gauze exhibits physical properties similar to ordinary surgical gauze; its absorbent power and bursting strength is approximately 80 per cent of strong Hessian (closer woven); alginate cloth has an even higher strength.

(E) *Foam*: The calcium alginate foam swells in water but does not become water-logged.

*Sterilization*: All alginate products subsequently used in physiologic experiments were submitted to a routine bacteriologic control. Tests were also carried out with alginate products previously inoculated with bacteria. The following table shows the results of these tests:

Material	Inoculum	Culture Medium	Method
Sodium alginate powder	<i>Staph. aureus</i> and <i>B. sporogenes</i>	Nutrient broth 37° C., 48 hrs.; and Robertson's meat broth 37° C., 3 days, respectively	Autoclave for 20 mins at 15 lb./sq.in. pressure
5 per cent Sod. alginate sol.	<i>Staph. aureus</i> and <i>B. sporogenes</i>	Nutrient broth 37° C., 48 hrs.; and Robertson's meat broth 37° C., 3 days, respectively	Autoclave for 20 mins. at 15 lb./sq.in. pressure
Calcium alginate film	<i>Staph. aureus</i> and <i>B. sporogenes</i>	Nutrient broth 37° C., 48 hrs.; and Robertson's meat broth 37° C., 3 days, respectively	Autoclave for 20 mins. at 15 lb./sq.in. pressure
Calcium alginate gauze	<i>Staph. aureus</i> and <i>B. sporogenes</i>	Nutrient broth 37° C., 48 hrs.; and Robertson's meat broth 37° C., 3 days, respectively	Autoclave for 20 mins. at 15 lb./sq.in. pressure
Calcium Alg./plasma sheet	<i>Staph. aureus</i> and <i>B. sporogenes</i>	Nutrient broth 37° C., 48 hrs.; and Robertson's meat broth 37° C., 3 days, respectively	Autoclave for 20 mins at 15 lb./sq.in. pressure

Result: All the above materials were found sterile after this treatment. There was no impairment of physical properties of the respective products.

*Biochemic*: Various grades of sodium alginate were found to accelerate the sedimentation rate of red blood cells. The higher the molecular weight, the more marked was this reaction. Injected intravenously into rabbits, 75 mg./Kg. of sodium alginate, *per se*, was not toxic,<sup>10</sup> if a calcium chloride solution (6 mg./Kg.) was injected intravenously within ten minutes following the injection of sodium alginate, however, the animals invariably died. There is no record available, as yet, whether delayed injection of calcium chloride had the same action.

When sodium alginate and calcium chloride were injected into muscle or the peritoneal cavity, no toxic reaction followed. Noninterference of either sodium alginate or calcium alginate with enzymic activity *in vitro* was also demonstrated.<sup>11</sup>

On applying sodium alginate to a pool of blood, a rapid and marked syneresis was noticed. Films showed rouleaux formation or aggregation of red blood cells of true hemoagglutination type. This phenomenon was found to be in inverse ratio to the viscosity of sodium alginate used.

Tried as a plasma substitute, sodium alginate solutions clumped red blood cells *in vitro* and *in vivo*. It was, therefore, useless as a substitute material in transfusion.<sup>10</sup>

Gough<sup>12</sup> found that the injection of sodium alginate into bronchi in cases of pulmonary tuberculosis successfully blocked tuberculous cavities with no ill effects to the patient.

*Physiologic:* A number of experiments were carried out to establish the behavior of calcium alginate in animal tissues.

Complete absorption of all alginate products was established in every case. There was no qualitative difference in the biologic properties of alginate products. "Pearls" of calcium alginate absorbed in the same way as did film or gel.

The experiments can be tabulated as follows:

1. Behavior of clot formed by sodium alginate and calcium chloride injected into tissue.
2. Behavior of prepared calcium alginate film inserted into tissue.
3. Behavior of locally clotted calcium alginate and of calcium alginate plasticized with plasma on denuded surfaces.
4. Behavior of calcium alginate gauze in internal hemorrhage.

(1) *Calcium Alginate Clot Formed in situ, by Injection:* In this series rabbits were used. The method adopted was as follows: The injection of the two reacting substances was made through separate syringes and needles to prevent clotting in the syringe or needle. A wide-bore needle was used to inject the viscous sodium alginate solution. The materials used were 3 cc. each of 5 per cent sodium alginate and 2 per cent calcium chloride. Sodium alginate was injected first; the calcium chloride was injected into the mass of sodium alginate. A clot was palpable immediately. The site of injection was the rectus femoris muscle. As controls, 5 per cent sodium alginate was injected in one group, and 2 per cent calcium chloride in another.

Sections were taken from the respective sites a week, or longer, after the injection. The animals were anesthetized by intraperitoneal nembutal.

While the control animals showed no trace of any injected substance, and no clots were palpable at any time during the experimental period, those injected with the combination of sodium alginate and calcium chloride had a palpable clot at the injected site 24 hours after the injection. This clot was easily palpable for a few days, after which period it gradually disappeared. The average final disappearance was 10-14 days.

FIG. 1.—Photograph of various alginate products.

- (A) Calcium alginate cloth.
- (B) Calcium alginate yarn (polyfilament).
- (C) Calcium alginate film.
- (D) Calcium alginate gauze.

FIG. 2.—Remains of calcium alginate clot at seven days. The dark amorphous masses are calcium alginate. The margins of the masses are seen to be penetrated and fragmented by invasion of polymorphonuclear leukocytes. No giant cells are present.

FIG. 3.—Calcium alginate clot at 14 days. The small amorphous clot is seen in the final stages of disintegration by fibrocytes. There are no more polymorphs visible. Foreign body cells are not found.

FIG. 4.—Appearance of a bone-gap filled with alginate at four weeks. There are only minute traces of CaAlg at the margins of the line of junction. Bone and site of union look normal.

FIG. 5.—Control at three days. The transverse section of the femur (guinea-pig) is shown at three days. Muscle, bluntly dissected, was allowed to fall back in place. An area of hemorrhage and a massive polymorphonuclear reaction is seen.

# ALGINATE PRODUCTS IN SURGERY

FIG. 1

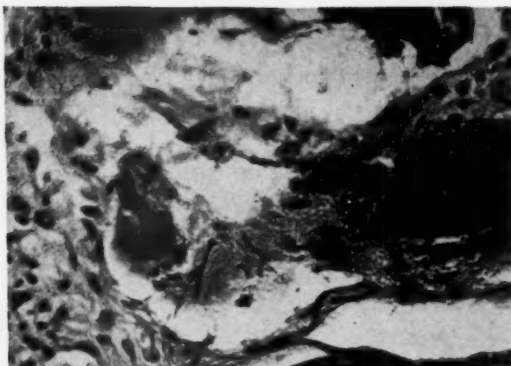
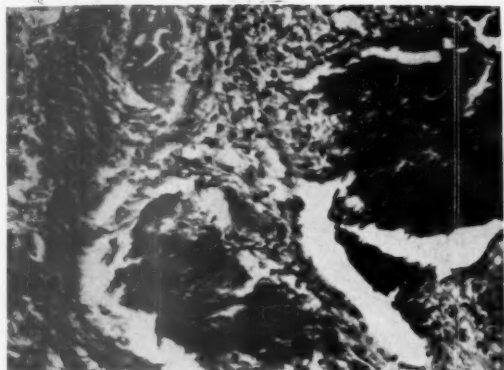
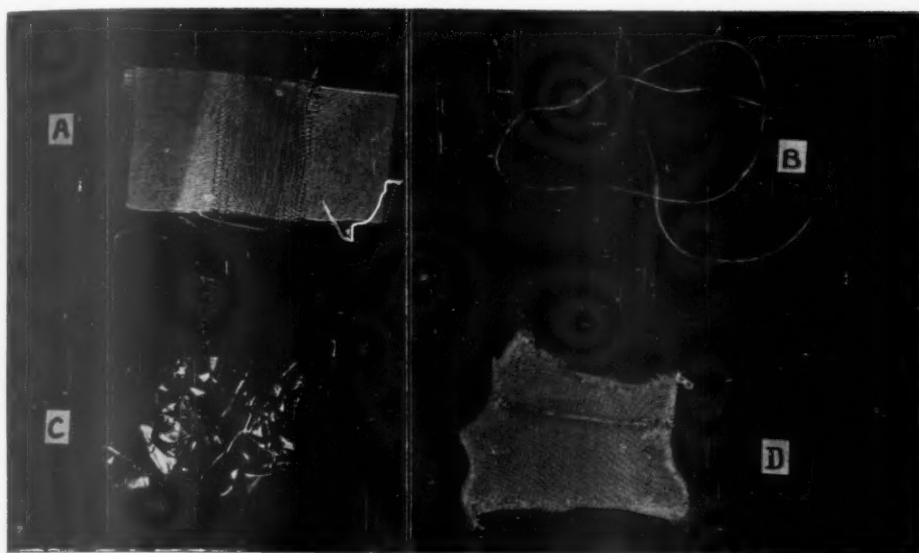


FIG. 3

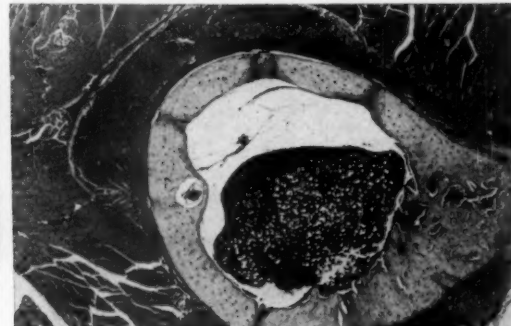
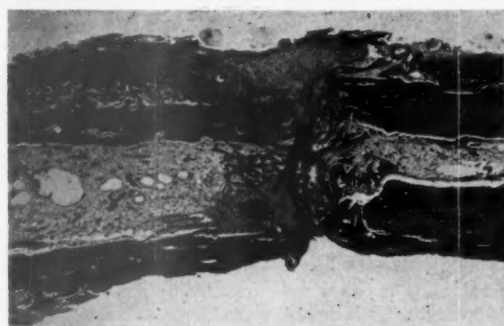


FIG. 5



Sections fixed in alcohol and stained with hematoxylin-eosin, and in some cases with indigo-carmin, showed a progressive absorption of the amorphous clot by phagocytosis. Figure 2 shows the appearances of remains of a clot seven days after injection. The clot shows up as a slightly basophilic amorphous mass, broken up into fragments, and the margins are invaded by polymorphonuclear leukocytes. There is a marked polymorphonuclear leukocytosis around the area, denoting an aseptic inflammatory process. No foreign body giant cells are visible. At 14 days (Fig. 3) leukocytosis has subsided. There is massive fibrous tissue invasion of the remaining fragments of the clots, while some parts of it are already replaced by fibrous tissue. No foreign body giant cells are visible in the section.

In another series of rabbits, clots were prepared *in situ* in sites prepared in the radius of the animal. The rabbits were anesthetized by intraperitoneal nembutal. The foreleg was shaved and incised over the shaft of the radius. A length of 2-3 mm. was sawed out of the shaft of the bone, and the clot was inserted *in situ* by dropping a few drops of 5 per cent sodium alginate into this bed, followed immediately by calcium chloride drops over it. The clot was at once seen to contract and it was then gently moulded into the bone-gap. Fascia and skin were then sutured with silk. In some animals, the strength of the clot was altered by using a 3 per cent solution of sodium alginate and drops of 0.5 per cent calcium chloride, in order to compare the respective rates of absorption.

The animals were killed two and four weeks after the operation, and the bone was removed for decalcification, fixation, staining and serial section. The paraffin wax method was used after decalcification.

Figure 4 shows an alginate clot-filled bone-gap four weeks after the operation. Only minute traces of the clot are visible; the gap is filled with new bone, and the bone looks normal.

In bone-gaps filled with the weaker concentration of clot (3 per cent NaAlg and 0.5 per cent  $\text{CaCl}_2$ ), the appearances are at two weeks similar to those seen in Figure 4, at four weeks, after the insertion of a 5 per cent sodium alginate and 2 per cent calcium chloride clot.

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FIG. 6.—Control at seven days. The hemorrhagic area is decreasing. Fibroblasts are seen to replace the early polymorphs. Repair is in progress.

FIG. 7.—Calcium alginate film around femoral shaft at three days. Areas of hemorrhage are seen around the film. Massive polymorphonuclear reaction is seen.

FIG. 8.—Calcium alginate film around femoral shaft (guinea-pig) at seven days. The bone shows periosteal proliferation. Only a thin trace of film is visible in one area. Fibroblasts and a few macrophages are seen. Repair is in progress.

FIG. 9.—Scleral wound in the eye of a rabbit at seven days. There is only a thin roof of conjunctiva over the gap which is not yet healed (control.)

FIG. 10.—Scleral wound in the eye of a rabbit at seven days. Treated with calcium alginate film placed between conjunctiva and sclera. The wound is completely healed. The film is still visible as a thickening of the wound site. It is invaded by fibroblasts and is being replaced by tissue.

FIG. 11.—Burn (rabbit) at three days. The burnt area shows necrosis of the epidermis and disappearance of the hair follicles.



FIG. 7

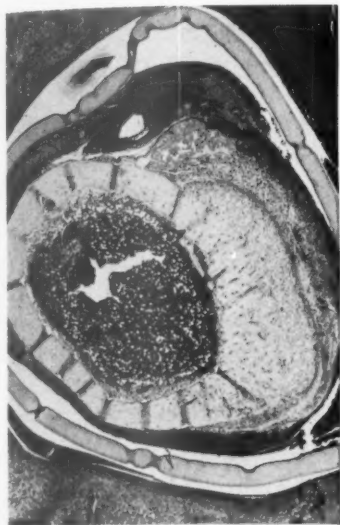


FIG. 9

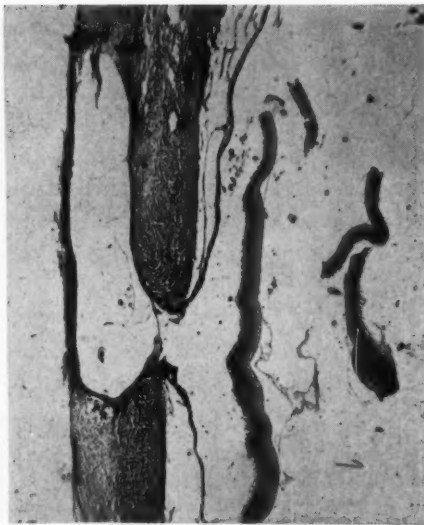


FIG. 11



FIG. 6

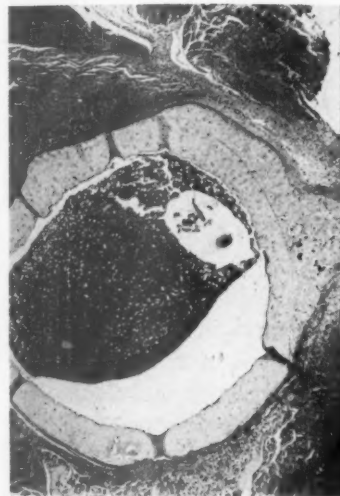


FIG. 8

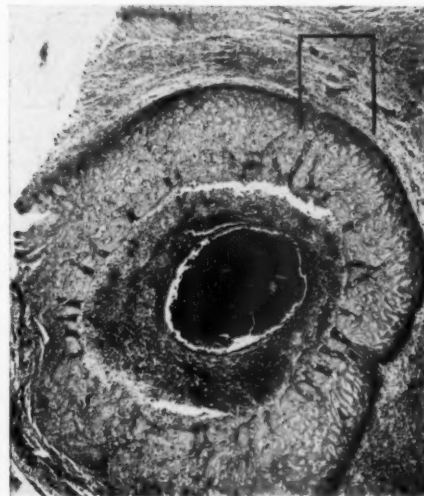


FIG. 10



(2) *Calcium Alginate Film in Tissue*: Three series of experiments were carried out with films. Rabbits and guinea-pigs were used.

In the first series films of 80  $\mu$  thick calcium alginate was introduced around the femoral shaft of the guinea-pig, from which the muscle was detached by blunt dissection. The other femoral shaft was used as a control, using no material to wrap round the bone; the muscle was detached by blunt dissection and was allowed to fall back into place. The wounds were closed with silk sutures, and the animals were sacrificed at periods of 3-7-14 days after the operation. The bone and the surrounding muscle were removed *en bloc* for section. Intraperitoneal nembutal was the anesthetic in all operations.

Figures 5, 6, 7 and 8 show the respective appearances of some of the specimens. In the controls, a marked aseptic inflammation (polymorphonuclear leukocytosis) is visible at three days. At seven days the inflammation has subsided and fibroblasts appear. The bone is reacting with a new layer of periosteal bone.

In the sections showing the appearances of the femoral shafts around which calcium alginate films were wrapped, the reaction is much the same. Around the edges of the film there is a marked hemorrhagic and polymorphonuclear reaction at three days; at seven days there is normal progress of repair with invasion of lymphocytes and fibroblasts. There are a few macrophages in the section. At 14 days a trace of the calcium alginate film only is detectable. The area occupied by it is replaced by fibrous granulation tissue and the bone shows signs of periosteal activity.

In the second series of animals calcium alginate film was introduced into traumatized muscle. After intraperitoneal anesthesia by nembutal the rectus abdominis was opened through a paramedian incision, and was traumatized by blunt dissection. A postage stamp-sized film was introduced into the site thus prepared. To facilitate the removal of the biopsy specimen a green nylon suture was inserted near the site. Biopsy four weeks after insertion of the film showed complete absorption of the film and only a small fibrous cicatrix amidst healthy muscle bundles was visible at the site of insertion.

In the third series (reported on fully elsewhere<sup>13</sup>), rabbits were used; and calcium alginate film was introduced in the cocaine-anesthetized eye of the animal, between the conjunctiva and the sclera, in the region of the limbus. The object of this experiment was to demonstrate the tissue reaction and tissue isolating behavior of calcium alginate and to find out whether it was of use in the prevention of vitreous prolapse through incised wounds of the sclera.

Figures 9 and 10 show sections through the eyes of two rabbits; in one a calcium alginate film was inserted between the conjunctiva and sclera; in the other, section of a control eye is shown. Both specimens are from eyes one week after operation.

The control section shows a marked gap in the sclera, which is notoriously slow in healing; only a thin roof of conjunctival tissue has reformed. In the treated eye, the gap in the sclera is completely bridged by fibrous tissue with

elements of true scleral fibers; the calcium alginate film is shown invaded by fibroblasts, and is in the process of final fragmentation. There were no conjunctivoscleral adhesions.

(3) *Local Clotting of Alginate (and Alginate Plasma) on Burns:* In this series burns were produced on the shaved backs of rabbits with electrocautery, after preliminary intraperitoneal nembutal anesthesia. Two burns were created on each animal; on the one side, a clot of calcium alginate, or calcium alginate with plasma, was produced; on the control side the burn was treated with a saline wash followed by triple-dye paint. Between the infliction of the burn and the start of the treatment five-minute intervals were kept. The method of producing the alginate or alginate plasma clot was as follows: One drop of 5 per cent sodium alginate (with or without plasma) was allowed to spread on the burn; one drop of 2 per cent calcium chloride solution was added to the spread out film, producing the clot immediately. The animals were sacrificed at three and seven days, respectively, after the infliction of the

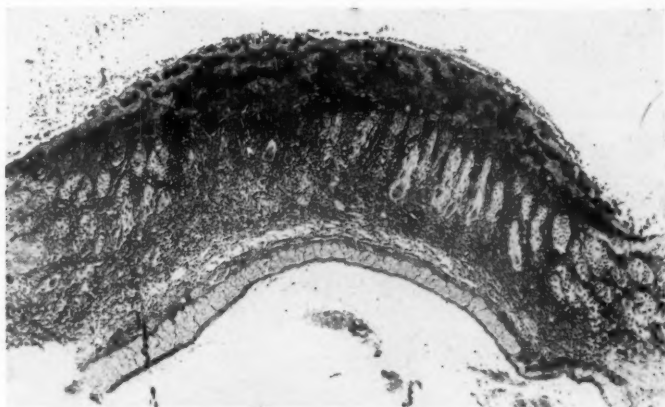


FIG. 12.—Burn (rabbit) treated with calcium alginate clot at three days. A thin surface of epidermis is necrosed and debris are incorporated in the clot. The underlying tissue is edematous, hair follicles are present and degeneration is far less advanced than in Figure 11.

trauma. The area of the burns was removed and submitted for serial sectioning.

Figures 11 and 12 show the appearances three days after the burn. In the control animals, the whole area of the burnt epidermis presents as necrosed tissue. All hair follicles have disappeared from this area (Fig. 11).

In the burn treated with calcium alginate, the appearances are vastly different. A thin surface layer of the epidermis is necrosed and mixed up with parts of the film which seems to have taken up the necrotic debris in its substance. The underlying tissue shows a fair degree of edema, but degeneration has not taken place to the extent it has in the control burn. Some hair follicles remain and look normal.

FIG. 13-A

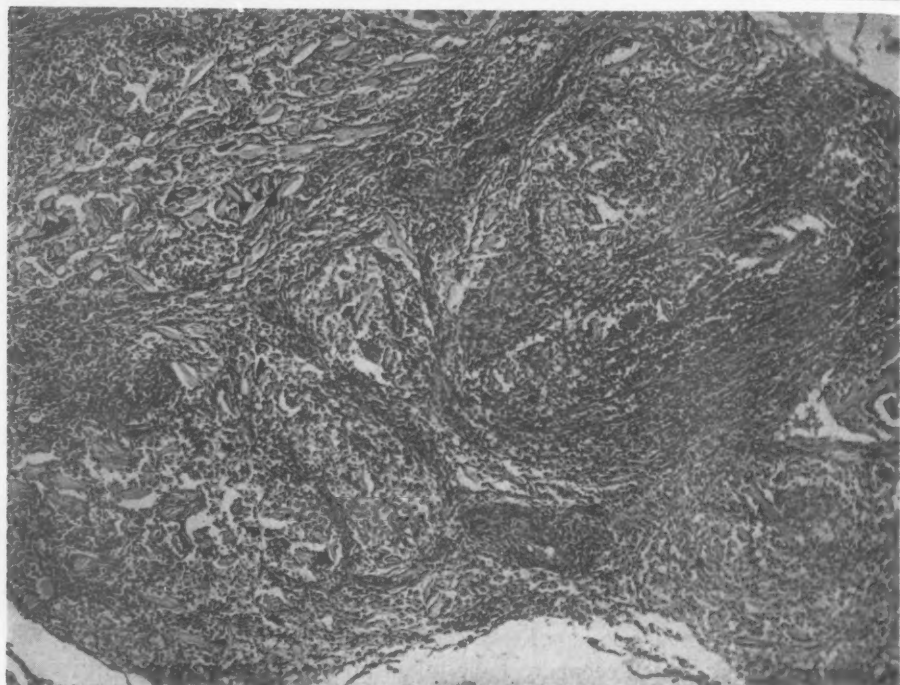
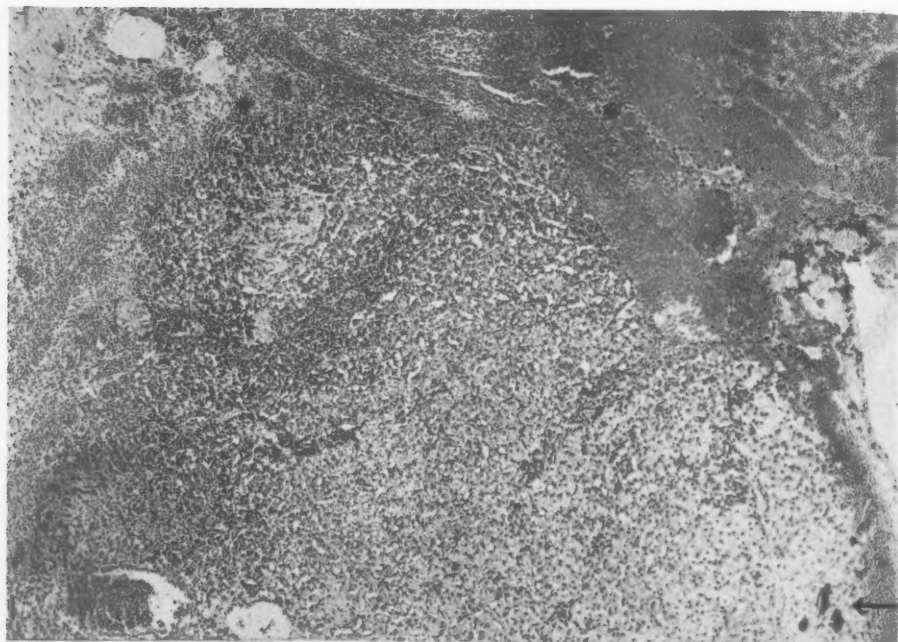


FIG. 13-B

FIG. 13.—A and B.—Liver (cat) six weeks after resection of oval area from liver substance. The liver looks normal. At the wound site many alginate gauze shreds are visible. These shreds are in process of absorption and numerous fibroblasts and a few foreign body giant cells are visible.



In the animal burns examined seven days after infliction of the thermal trauma the appearances are again in marked contrast. The triple-dye treated side is necrosed, there is some fibroblastic reaction from the periphery; hair follicles are absent. In the alginate-treated side the regeneration of tissue is more marked, some hair follicles are present and appear normal. Almost identical findings were made in the cases treated with the alginate-plasma clots.

(4) *Calcium Alginate Gauze in Capillary Hemorrhage:* In this series of experiments cats were used. After intravenous nembutal anesthesia a high paramedian incision was made to the right of the midline. The left lobe of the liver was pulled out of the wound by traction, and a deep oval area was resected

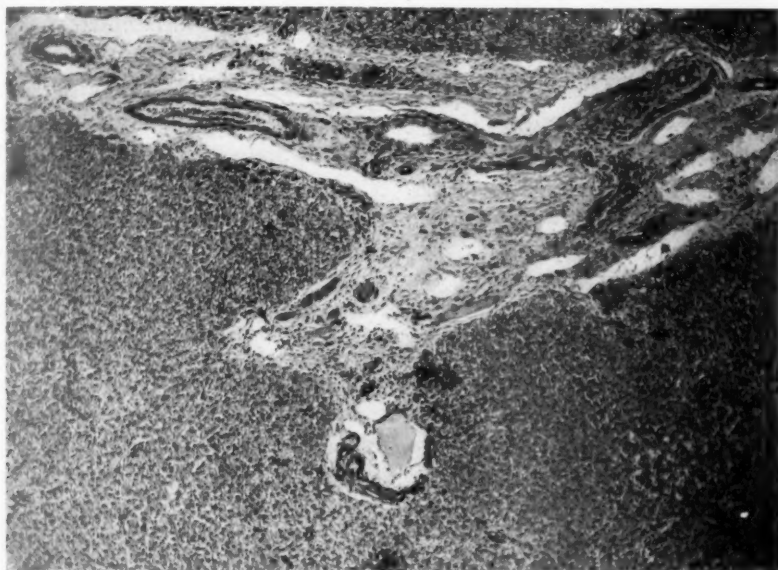


FIG. 13-C.—Section from liver of cat (Figs. 13-A and 13-B) showing alginate gauze shreds in course of disintegration. Fibrocytic reaction around shreds of material. Surrounding liver normal.

from the organ. There was immediate copious hemorrhage from this area, into which calcium alginate gauze was packed, under slight pressure. No sutures were inserted to anchor the gauze which became quickly clotted to the surrounding area.

The cats were kept alive for six weeks. After the first few days during which they were restless and did not touch their food, and had no bowel or bladder action, their appetite returned, defecation and micturition became normal. Recovery was uneventful, and at the time of sacrificing the animals for section they were in good health.

The microscopic appearances of these liver sections was in conformity with the previously reported observations on the behavior of calcium alginate in



tissue. Shreds of the material appear as profuse hyaline masses, all of which appear to be in a process of digestion by phagocytic action. Numerous fibroblasts and some foreign body giant cells are present. The surrounding area of the liver shows normal granulation tissue. Some muscle bundles, involved in the section, are being replaced by fibrous tissue (Fig. 12). In other sections there are traces of more marked hemorrhages in the liver. The area around these clots looks normal. Inflammatory cells are still present at the periphery of the hemorrhages and scanty shreds of alginate gauze surrounded and being digested by phagocytes can be identified.

In all the six cases of experimental hepatic hemorrhage the massive bleeding was promptly controlled by packing the oozing area with the alginate gauze.

From the foregoing experiments on alginate products, it becomes clear that this substance, used as a clot, film or gauze, is absorbed in animal tissues. Tissue reaction to it is minimal; its rate of absorption can be varied by using various strengths of sodium alginate or calcium chloride. The absorption rate, naturally, further depends on the physical form and bulk of the product. Thus, alginate cloth or gauze is slowest, and thin alginate film quickest in absorption in living tissue.

Preliminary bacteriostatic experiments have further shown that alginate products are readily sterilizable by autoclaving; preliminary experiments (not yet reported on) with penicillin have established that alginate products had no inhibitory action on penicillin.

It is hoped that this report on the possible uses of alginates in surgery will awaken further interest. Exigencies of the service in war-time have made it impossible to conduct a more complete examination of the many problems at issue. It has been shown, however, that alginates possess certain properties which make their surgical use attractive.

I wish to express my thanks to Lieut. General Sir Alexander Hood, Director-General, Army Medical Services, for permission to publish this paper.

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## NUTRITIONAL REHABILITATION OF SURGICAL PATIENTS

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MANY RECENT ADVANCES in medicine can be attributed to a better understanding and application of the basic medical sciences. The needs of patients for fluids and electrolytes have been studied and determined by many investigators and the value of transfusions of blood and plasma now are well-recognized. Gastro-intestinal decompression, as well as chemotherapy, control of bleeding and clotting, and the newer products, such as penicillin, have all aided in better care of patients.

The nutritional state of the patient long has been recognized as an important factor in surgical risk and convalescence, but the importance of thorough understanding is only now beginning to be appreciated. Ravdin, and his associates,<sup>17, 22</sup> as well as others,<sup>2, 9, 16</sup> have called attention to the importance of adequate nutrition in surgical patients. Recently, Mulholland, and his coworkers<sup>4, 15</sup> pointed out that the postoperative convalescence of patients who have undergone gastrectomy and who are fed by tube and maintained in positive nitrogen balance, was much shorter with an actual gain in weight compared to a control group of patients who had undergone gastrectomy and received the usual postoperative care. Madden and Clay<sup>10</sup> have stated that high intake of protein compensates for increased catabolism resulting from injury to the body in experimental animals.

The need of a high protein diet in healing of wounds has been emphasized by Harvey and Howes.<sup>7</sup> Postoperative separation of abdominal wounds still occurred in dogs when every other factor except hypoproteinemia was controlled in experiments carried out by Thompson, Ravdin, and Frank.<sup>23</sup> The protective action of a high protein diet against a virulent strain of pneumococci has been demonstrated in mice by Sako.<sup>20</sup> Also, the protective action of a high protein diet against necrosis of the liver which was produced by chloroform anesthesia was demonstrated by Davis and Whipple,<sup>5</sup> in 1919, and more recently by Ravdin, and his group.<sup>6</sup>

Now that the importance of ingestion of protein is becoming more apparent, emphasis must be placed on the quality of protein<sup>11</sup> and its amino-acid content, as well as on the quantity of protein.<sup>19</sup> Miller, Ross and Whipple<sup>14</sup> have shown that methionine is the one amino-acid which protects protein depleted animals against necrosis of the liver which is produced by chloroform anesthesia.

The importance of vitamins is beyond dispute, but they perhaps have been given too prominent a part in the nutritional management of surgical patients at the expense of other equally important factors. Vitamin C is known to be a determining factor in the tensile strength of wounds<sup>1</sup> as well as the maturation of precollagen fibers.<sup>8</sup> However, there is evidence now that vitamin C is necessary for the complete metabolism of phenylalanine,<sup>21</sup> one of the essential amino-acids. Whether proper healing of wounds is dependent on vitamin C or on the availability of the essential amino-acids is yet to be determined. Mulholland, and his coworkers,<sup>16</sup> in an interesting report, pointed out the effect on healing of an adequate intake of nitrogen in a series of 35 cases of decubitus ulcers which had persisted in spite of high vitamin, high caloric diet.

Patients who require operation for recovery often can be prepared by simple means rather than denied operation because of severe nutritional deficiencies. The following case illustrates what can be done in a seemingly hopeless case:

**Case Report.**—The patient, a male, age 53, was admitted to the Mayo Clinic in a critical condition and was hospitalized immediately. He had been operated upon elsewhere for obstruction of the small intestine three weeks before his admission. An enterostomy had been performed at that time. The incision had separated a few days post-operatively, and a loop of bowel had protruded and had been incised. Hence, two enteric stomas between which there was a very short loop of jejunum were present.

On examination, the patient was severely dehydrated and emaciated, and the abdominal incision was widely separated and raw. The upper enteric stoma was evidently high in the jejunum, as food taken by mouth would appear on the abdomen a few minutes after ingestion.

The level of hemoglobin was 13.0 Gm. per 100 cc. of blood. Erythrocytes numbered 3,790,000; and leukocytes 12,000 per cubic millimeter of blood. The sedimentation rate (Westergren) was 98 mm. in the first hour. The level of urea in the blood was 20 mg. per 100 cc. Temperature was elevated slightly, 100° F., and the respiratory rate was 20 per minute. Urinalysis gave negative results. A roentgenogram of the abdomen showed a short distended loop of small intestine. Proctoscopic examination and roentgenologic examination of the colon, made some little time after admission, failed to reveal any intrinsic intestinal disease.

The patient was given 500 cc. of whole blood and fluids parenterally. Aluminum paste was applied to the skin around the wound and continuous suction was applied to the wound. He had been on a general diet before admission, but this was discontinued as the food quickly appeared on the skin of the abdominal wall. Even a glass of milk or water acted as a bolus of food and was expelled through the enteric stomas. Food, prepared after the manner of Spies, was administered by drip through a stomach tube and this also quickly appeared on the abdomen.

In an attempt to utilize the short loop of small intestine between the stomach and the upper enteric stoma it was thought best to give nourishment slowly by the drip method that could be absorbed immediately and did not have to be digested. Nine hundred cubic centimeters of a 20 per cent solution of amino-acids\* in the form of an acid hydrolysate of casein was mixed with 2,000 cc. of 20 per cent solution of glucose. This solution which provided about 2,100 calories was given slowly by the continuous drip method through the nasal tube. The patient received daily 1,000 cc. of 5 per cent solution of glucose in distilled water intravenously and 1,000 cc. of saline solution to which was added 20 mg. of vitamin C and adequate vitamin B-complex. Although most of the food prepared by the Spies formula was expelled through the enteric stoma, about 1,000 cc. was given daily to provide additional calories.

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\* Supplied by Frederick Stearns & Company.

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This program was continued for two months. The patient gradually emerged from what seemed a hopeless condition. At first considerable quantities of the mixture passed through the enteric stoma, but this soon decreased. The patient was allowed out of bed on the 27th day. He weighed 119 pounds (54.0 Kg.) on the 39th day and 125 pounds (56.7 Kg.) on the 59th day. Although it was impossible to weigh him on admission, he certainly did not weigh much more than 100 pounds (45.4 Kg.).

At operation, two months after admission, the loops of small intestine were found to be matted together so that it was impossible to explore the peritoneal cavity. A lateral jejunojejunostomy was established between two loops of intestine, one about 5 inches (12.7 cm.) proximal and the other 5 inches distal to the proximal enteric stoma. A pelvic abscess was drained also. After the operation it was estimated that the jejunojejunal anastomosis side-tracked about one-fourth of the fecal current, so that the diverted fourth came through the distal enteric stoma and about three fourths through the proximal enteric stoma.

Five months after this operation the patient weighed 160 pounds (72.6 Kg.). At this time he was operated upon again and it was possible to close both enteric stomas. He has remained well since that time.

Although nitrogen balance has been maintained in man for as long as 17 days by the intravenous administration of a mixture of glucose, amino-acids, and an emulsion of fat,<sup>3</sup> the gastro-intestinal tract still remains the preferable route of alimentation of large amounts of nitrogen and nourishment. Most of the available preparations of amino-acids are made by the digestion of casein or fibrin and contain a high percentage of glutamic acid, the amino-acid which in recent toxicity studies<sup>13</sup> has been shown to cause vomiting when it is administered intravenously. Furthermore, studies of nitrogen metabolism<sup>12, 18</sup> have revealed that nitrogen administered orally in the form of amino-acids is utilized several times more effectively than when it is administered intravenously. The realization of the importance of nitrogen balance in preoperative, as well as in postoperative care, and the correction of serious imbalances will aid in lowering surgical mortality and morbidity.

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## A TECHNIC FOR TESTING HYPERTENSIVE PATIENTS PREOPERATIVELY\*

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SINCE 1930, numerous investigators have studied the cause or causes of hypertension, while surgeons have been interested in treatment by operations upon the nervous system. Allen and Adson,<sup>1</sup> Peet,<sup>2</sup> Grimson,<sup>3</sup> and Smithwick<sup>4</sup> have made contributions in this respect. At present, while students of the subject are still divided in opinion as to the advisability of surgical treatment, many surgeons now lean toward combined thoracolumbar sympathectomy as the best surgical therapy. Writers on this latter subject attest to the difficulty of properly selecting patients for operation; it is particularly difficult to predict accurately the result of operation insofar as lowering of blood pressure is concerned. Although improvement may follow sympathectomy with little or no significant lowering of pressure, it is generally agreed that it would be desirable to be able to predict this event preoperatively.

Recently, we reported our experiences with nerve blocking methods to predict the result to be expected from Smithwick's operation, insofar as lowering of arterial tension immediately postoperatively is concerned.<sup>5</sup> In this report the technic of testing is more fully described. If further experience with this test substantiates its validity, it may be possible to determine preoperatively the extent of sympathectomy necessary to produce a satisfactory response.

Detailed discussion of the cause of essential hypertension is beyond the scope of this paper. It is sufficient to say that experimental work at present indicates a sequence of events as follows: Some unknown factor, probably psychic, initiates increased blood pressure, at first labile, which presumably arises from arteriolar vasoconstriction; as the disease progresses arteriolar sclerosis occurs, notably in the kidneys, and perpetuates hypertension, keeping it, also, more or less fixed. Quite likely, from experimental work, a renal pressor mechanism plays a prominent part in maintaining pressure — almost certainly in the phase of arteriolar sclerosis and possibly earlier. Just when it begins to play a part is not certain. In the later stages, readily demonstrable kidney and cardiac disease occurs. Malignant hypertension is probably an instance of the same condition accelerated.<sup>6, 7, 8</sup>

Sympathectomy for treatment of essential hypertension is not supported by experimental evidence; this type surgery fails to prevent and does not reduce increased arterial pressure experimentally produced by Goldblatt's

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method.<sup>7</sup> Nevertheless, there is ample clinical evidence to support the belief that this type surgery, especially the Smithwick procedure, produces significant variation in the usual course of the disease. Even though hypertension may not be greatly reduced, regression in eyeground changes and particularly improvement in clinical symptoms have been observed many times. Symptomatic improvement may be explained away as a psychic effect, but regression of eyeground changes leads to the conclusion that the disease is modified. Final evaluation of results, however, awaits longer follow-up.

Granting that sympathectomy of the proper type in selected patients lowers blood pressure and produces profound changes and probably is of some curative value, by what mechanism does it produce its effects? How does it alter the mechanism of arterial tension? Some studies indicate that a change in renal hemodynamics occurs following operation, while others note no significant change in this respect. There is some evidence to indicate that the output of the heart is reduced with consequent reduction in pressure rather than any decrease in peripheral resistance. However, this concept fails to account for other changes produced by the operation. The answers to these questions likewise await the results of more study.

In an effort to duplicate the result of sympathectomy preoperatively, in order to study hypertension with pressure temporarily lowered, spinal anesthesia has been administered. Gregory, Lindley, and Levine<sup>9</sup> studied a number of hypertensive patients before, during, and after spinal anesthesia, and concluded that, since most responded with a fall in blood pressure, spinal anesthesia releases peripheral vasoconstriction which is the cause of much essential hypertension. This concept has been criticized<sup>10</sup> on the basis that vasodilatation produced by spinal anesthesia is postarteriolar rather than arteriolar, the seat of the underlying disturbance in hypertension. Page, and his coworkers, studying the effect of spinal anesthesia on hypertension, believe that patients fall into a neurogenic or humoral classification (although they believe that these are but two stages of the same condition) and that only neurogenic patients exhibit renal arteriolar vasodilatation under spinal anesthesia, with resulting blood pressure fall, and that such response, at least to a significant degree, does not develop in the humoral group (those with renal arteriolar sclerosis and self-sustained fixed hypertension).<sup>10</sup> They suggest that such a test as this — high spinal anesthesia — might afford a basis for differentiating patients in the early or neurogenic phase of the disease from those in the later humoral phase and that, in so differentiating, a basis for selection for sympathectomy might be found.<sup>11</sup>

Leaving aside the mechanism of action of spinal anesthesia in reducing the hypertension of some hypertensives, there are certain objections to its use for this purpose.

Spinal anesthesia produces a very profound effect; it reaches its height quickly and may overwhelm other blood pressure-compensating mechanisms, bringing about a quite precipitous fall. While this is not especially danger-

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ous, it may mask the true picture. Likewise, it produces widespread muscular relaxation which may affect return of blood to the heart to a significant degree. Lastly, spinal anesthesia sufficiently high to mimic an extensive thoracolumbar sympathectomy is not without danger of undue cephalad spread and respiratory embarrassment or failure.

Previously, we have studied, for other reasons, the effects of peridural anesthesia on blood pressure in both normals and hypertensives. Using peridural anesthesia as a general term to include its common forms, caudal analgesia and segmented peridural block, the following facts may be noted:

Anesthetic solution deposited into the peridural space, either at its distal end by the caudal technic or in the lumbar or thoracic region by the segmental technic, diffuses in the peridural space—in the former technic upward and in the latter both cephalad and caudad. It runs always outside the duramater and cannot rise farther than the foramen magnum. The anesthetic solution never enters the subarachnoid space, never mixes with the spinal fluid, and never can enter the cranium. Rather, it diffuses out the intervertebral foramina and blocks the nerves at or close to this point. The sensory and autonomic nerves are blocked first; it has been shown that when there is loss of pain perception in a given segment with this type block there is sympathetic block in the same segment. The motor nerves are not usually much affected even in those blocks made for anesthetic purposes; and with proper concentration of solution, motor block may be almost completely eliminated. By means of amount of solution injected, force of injection, and control of position of the patient, a sensory and sympathetic block of almost any desired extent can be achieved by one or the other of these methods. In testing hypertensive patients, the sympathetic block is of more importance but the sensory block serves to mark the limits of effect.

The effect of this type anesthesia on normotensives depends upon the number of sympathetic segments anesthetized and the rapidity with which the block is brought about. In addition, there seems to be a critical level peculiar to each individual, varying from the ninth thoracic to the fourth thoracic segment, where a significant pressure drop occurs. Anesthetizing a greater number of segments tends to produce a greater fall in pressure. Rapidly extending anesthesia beyond the limits of the critical level produces a more precipitous and profound effect.

In studying essential hypertensives, effects similar to those in normotensives were noted, with the exception that in some hypertensives no drop at all could be produced. Otherwise, as just mentioned, rapidly ascending or spreading anesthesia produces a precipitous fall. This may be quite alarming to watch, but we have noted no ill effects from it. Presumably it is due to the same cause that produces so profound an effect in high spinal anesthesia (unsupported by pressor drugs); namely, overwhelming of other compensating mechanisms. Likewise, in hypertensives, as in normotensives, greater fall is produced by block of greater extent. In those hypertensives

who respond to this anesthesia with decreased tension, there seems also to be a critical level somewhere between the ninth and fourth thoracic segments at which a marked fall begins.

As has been described in more detail elsewhere,<sup>12</sup> in a group of 60 patients with essential hypertension, anesthesia varying from the tenth to the fourth thoracic segments produced a blood pressure fall to normal levels (below 140/90) in all but ten. These ten were not necessarily in the most malignant or advanced phases of hypertension, as judged by other clinical tests. An attempt to explain this fixation of pressure on the basis of the probable pathogenesis of hypertension would be conjecture at this time, but it seems reasonable to assume that, whatever the mechanism, it has reached an irreversible stage and presumably these patients would not be benefited by sympathetic surgery.

Aside from technical differences, the two methods of peridural anesthesia differ somewhat in their effects on the autonomic nervous system. Caudal analgesia, induced from the distal portion of the peridural space, blocks all the sacral segments—both somatic and autonomic—in addition to the lumbar and thoracic segments. Lumbar peridural anesthesia, on the other hand, may be adjusted to produce a block that quite closely approximates the Smithwick operation in extent of sympathetic denervation without producing any effect in the sacral segments. In a number of patients in whom both peridural and caudal blocks were performed, we have noted no differences in the effect on blood pressure. Presumably caudal analgesia produces vasodilatation in the pelvis which a well-adjusted peridural block does not; both produce vasodilatation in the lower extremities and in the thoracic area.

Quite empirically, we have used caudal analgesia and lumbar peridural anesthesia by the continuous technics to study patients with hypertension later operated upon by the Smithwick procedure. In a small group of patients there seems to be good correlation between these tests and the immediate postoperative recumbent blood pressure.<sup>12</sup>

#### TECHNIC OF CAUDAL ANALGESIA

Previous to administering caudal analgesia in the hypertensive, the status of kidney and cardiac function should be determined. Pressure should be reduced to as low a level as possible by medical regimen, such as rest and sedation. On the day of the test the patient may have a light meal; it is advisable to administer pentobarbital grains one and one-half an hour prior to the test. The anesthesia should be conducted in a quiet room by an operator in whom the patient has confidence. The blood pressure in one or both arms and in the lying position is noted.

A caudal needle is inserted into the sacral canal and attached to a reservoir of anesthetic solution. Care should be taken to avoid intravascular placement of the needle. We use metycaine 1 per cent or 1.5 per cent without addition of epinephrine. A test dose of 8 cc. of this solution is ad-



ministered and the effect observed for five minutes to determine that the needle has not been accidentally inserted into the subarachnoid space. If spinal anesthesia is not produced by this preliminary injection, 30 cc. of anesthetic solution is slowly given. The blood pressure is observed and recorded every 5 minutes. Thirty minutes after the injection of the initial dose, its maximum effect will have been achieved, usually to the tenth thoracic segment, as shown by testing the skin of the abdomen with a needle. Small patients, or the elderly, may require only 20 cc. as an initial dose.

If a higher level of anesthesia is desired at the end of the first period, a supplementary dose of 40 cc. of anesthetic solution is injected for the average patient. By this time, however, the operator will have a valuable guide to the individual response to this anesthetic procedure. If 30 cc. has produced effect well above the average, say to thoracic eight, he can assume that a second dose of 30 cc., rather than 40 cc., may be sufficient to raise the pressure to thoracic four or six, as height of effect in these doses is somewhat cumulative. On the other hand, if the original 30 cc. produces anesthesia to thoracic 12 only, it may be advisable to administer 50 cc. as the second dose to produce the desired level.

To determine the critical level at which a significant change occurs, blood pressure readings and skin testing should be performed every five minutes as the end-point may be quite sharp and might be missed during a longer interval.

In some patients we have found it necessary to administer as much as 40 cc. of solution every 20 to 30 minutes for three or four doses to produce a high level of skin anesthesia. If this amount is not effective it is our custom to discontinue caudal anesthesia and after a few days resume the test using the peridural technic outlined below.

In the average patient 70 cc. of anesthetic solution administered in two doses 30 minutes apart will produce anesthesia to thoracic six to four. To maintain this level for a time, further supplementary doses of 30 to 50 cc. every 45 minutes will be required according to the individual response of the patient. Should undue difficulty be experienced in raising the level of anesthesia, the table may be tilted to five-degree Trendelenburg position. Gravity will assist the solution in diffusing upward. If the anesthesia goes so high that a below-normal blood pressure is produced, cerebral anoxia may be prevented by elevation of the lower extremities on pillows. When the high level recedes, the test may then be continued, using smaller amounts of solution.

In using caudal analgesia for testing hypertensives, the general precautions and contraindications that apply to this method under other circumstances should be observed.<sup>13, 14</sup> This technic should be avoided in the presence of infections of the skin, particularly if near the needle site. Deformity of the sacrum or obesity may render the technic difficult. We have avoided this test when there is evidence of coronary artery insufficiency.



## TECHNIC OF LUMBAR PERIDURAL ANESTHESIA

Segmental block of the thoracic and upper lumbar somatic and sympathetic nerves can be achieved readily by lumbar peridural block since there is less space to be filled before reaching the desired nerves. Using Abajian's<sup>15</sup> technic, which is essentially a single dose procedure, it is often possible to obtain quite accurately delimited anesthesia. For ease of control, however, we have preferred continuous lumbar peridural anesthesia when caudal block is not practicable.<sup>16</sup> Using the continuous method, more accurate block can be achieved.

The patient is placed on a Lemmon continuous spinal mattress and the spine is flexed as for lumbar puncture. A malleable steel needle is inserted at the first or second lumbar interspace down into the interspinous ligaments. The stylet is then withdrawn and a 2 cc. syringe containing saline is attached to the syringe. The needle and syringe together are advanced through the ligaments. At the moment the point of the needle enters the peridural space the saline solution rushes in, pushing the dura forward. At this point progress of the needle is stopped. If no spinal fluid appears on aspiration, tubing to a reservoir bottle is attached to the needle, and the patient is turned to the recumbent position. Five cubic centimeters of 1.5 per cent metycaine solution are then injected and the effect observed for five minutes, an additional test to prevent intraspinal injection. If 5 cc. produces no demonstrable effect after five minutes, it is safe to proceed.

Twenty cubic centimeters of solution are injected for the initial dose, and skin anesthesia and blood pressure are determined every 5 to 15 minutes. At the end of 30 minutes, maximum effect of the initial dose will have resulted. Before injecting supplementary doses, the anesthetic status of the patient must be tested each time. Motor effects in the lower extremity are minimal or absent from these small doses peridurally. As an additional precaution before every injection, 5 cc. of 1.5 per cent metycaine solution are injected. If no widespread motor effects are observed after five minutes, the operator is assured that the needle has not shifted into the subarachnoid space. A supplementary injection of 15 to 30 cc. may be administered to extend or maintain the desired anesthesia.

The initial injection of 20 cc. of 1.5 per cent metycaine at the first lumbar interspace with the patient level usually produces a band of somatic and sympathetic anesthesia from T8 to L1 segments inclusive in the average adult male 30 minutes after injection. From this effect some fall in pressure is usually observed. A supplementary injection of 20 cc. 30 minutes after the initial injection reinforces the first anesthesia and usually extends it from T6 to L3 inclusive. As in caudal block, gravity may be used to influence spread of the anesthetic solution through manipulations of the table shortly after an injection.

From a theoretic standpoint at least, lumbar peridural anesthesia is a better test because of the reasons mentioned above. It more nearly repro-

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duces the denervation achieved in thoracolumbar sympathectomy. We find it technically more difficult and for this reason employ high caudal block whenever possible.

### SUMMARY

Experience with caudal and peridural anesthesia in hypertensive patients indicates that these technics may be used to predict the result of sympathectomy. The technic of application is described.

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## UTILIZATION OF SKIN FROM DEFORMED AND USELESS FINGERS TO COVER DEFECTS IN THE HAND

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GUNSHOT WOUNDS of the hypothenar eminence of the hand, with or without fracture of the fifth metacarpal, frequently result in extensive scarring of the area and irreparable damage to the tendons, with resultant flexion contracture of the fifth finger, rendering it useless.

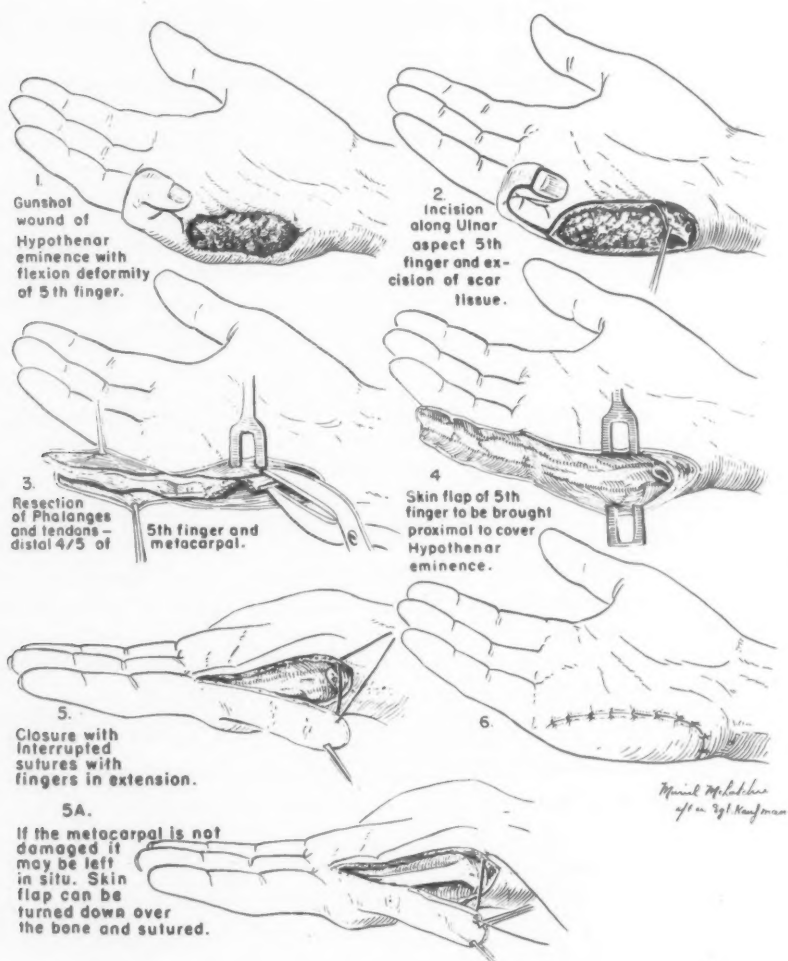


FIG. 1.—The above drawings illustrate the operative procedure for excision of scar and subcutaneous amputation of phalanges and metacarpal at the same time utilizing the skin flap to cover the defect created.

## SKIN GRAFTS FOR DEFECTS IN HAND

To correct this condition the following operative procedure has been used: (1) The incision circumscribes the nail and extends proximally along the ulnar aspect of the finger and around the margin of the scar. (2) The scar is excised completely down to the metacarpal. (3) If there has been extensive bone loss of the metacarpal, with nonunion, this bone is resected distal to its base. (4) The phalanges and tendons are removed subcutaneously. (5) The remaining skin flap, with its nerve and blood supply intact, is turned proximally to cover the skin defect. (6) As the flap is sewed with interrupted cotton or silk sutures, the remaining fingers are held in complete extension.

The value of this plastic procedure on the hand emphasizes the importance of preserving all possible skin of the hand at the time of the initial débridement when wounds of the hands have been sustained. The type of flap-graft described heals quickly and adjusts readily to its new location, because the circulation and nerve supply are preserved. The principles of this operation can be applied to cover any skin defect in the hand when it is associated with useless and deformed fingers.

The operation described was performed on five patients at the 105th General Hospital in the Pacific Theater. There was no difficulty in survival of the skin flaps. All grafts took readily, and the hands of all five patients were useful within two to three weeks after operation.

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## BOOK REVIEWS

SCIENTIFIC MEDICAL AND TECHNICAL BOOKS PUBLISHED IN THE UNITED STATES OF AMERICA 1930-1944. Edited by R. R. Hawkins, National Research Council, Washington, D. C., 1946.

THIS IMPRESSIVE REFERENCE WORK of over eleven hundred pages was prepared under the direction of the National Research Council's Committee on Bibliography of American Scientific and Technical Books, and was edited by Mr. R. R. Hawkins, Chief of the Science and Technology Division of the New York Public Library. As its title implies, it comprises a selected list of scientific medical and technical books still in print, written by American authors, and published in the United States during the years 1930 to 1944, inclusive. It was the original intention of the Committee to include all important scientific and technical literature that met the requirements of nationality, date of publication and availability. However, to keep the work within practical limits, it was necessary to limit the field covered and the type of publication listed. Social sciences (economics, education and criminology) are excluded. The rest of the field of science is well covered. In the field of Technology, graphic arts—printing, photoengraving and allied subjects are omitted. High school and elementary textbooks are eliminated, and publications issued by states and territories with the exception of books from state university presses.

Selection of books for inclusion in this bibliography is based on works of merit currently in print and available for distribution in America and foreign countries, and represents publications one would expect to find on the shelves of a modern up-to-date library specializing in a given subject. It should be useful to librarians, professional and technical research workers, scholars and teachers in the fields covered.

This work lists about six thousand books, and describes them fully with complete titles, tables of contents, and descriptive rather than critical annotations. It includes kinds of illustrations, price, and size of book in height given in centimeters. The list is not intended to be a bibliography of best books, but is rather a descriptive compilation of important and useful publications in the various fields of science.

The arrangement of the work is well planned with table of contents, subject index, author index and directory of publishers. In order not to make it too voluminous to be practical, the Committee found it necessary to eliminate worth-while state government publications. To partially compensate for this, the editor includes a directory of state agencies in the United States issuing publications in geology, engineering and agriculture.

The typographical format of the work is an excellent example of modern printing art. Its style of arrangement and general make-up show unusual judgment and skill in the selection of type sizes and spacing, and aid the reader to find his information easily and quickly. At the same time, its unique design compresses a vast amount of important and condensed information on each page.

This publication is without doubt the most complete in its field. The majority of other similar works are little more than lists of authors and titles of publications, with almost no descriptions of contents of books listed. Never before has the field of American scientific and technical literature been so completely and accurately surveyed.

The work should prove an excellent means of furthering our cultural relations with other countries. The Department of State of the United States has made the first printing available as an official document for distribution in Central and South American countries. It is expected that later printings will also be available for the liberated countries of Europe and the Far East.

Books on scientific medicine, dentistry and closely related subjects are well covered and comprise over 300 pages of the text, or almost one third of the work. Those on forensic medicine and the social aspects of medicine are eliminated together with publications on the costs of medical care and the socialization of medicine, even though there is extensive published literature on this subject.

This handy reference work is recommended to anyone having to do with the dissemination of scientific and technical knowledge in books, or about them—dealer, librarian, research worker or scholar.

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